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HISTOGENESIS OF THE RETINA¹

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INTRODUCTION

THE histology of the vertebrate retina has been carefully investigated in several animals and the adult structure of that organ is now fairly well understood, but the development of the retinal elements has received very little attention. The literature on the eye deals chiefly with the formation of the optic vesicles and with the histology of the adult organ. The only writer who has attempted to follow out the histogenesis of the retinal elements appears to be Cameron (:05) in a series of papers on the development of the retina in Amphibia, while Bernard (:00-:04) has given some attention to the development of the rods and cones. The investigations on which the present paper is based, were made on the retina of the chick. This animal was selected for study, first because it has never been investigated before, and second because it affords so readily a complete series of stages of development so that there need be no gaps for lack of material. Since it has been necessary to compare the results obtained here with those of Cameron, his technique has been followed closely, but in addition certain modifications of it have been used, for while in many cases by using his methods results precisely similar to his have been obtained, yet by other methods results more in accord with the known processes of cell and tissue development in other organs of the body have been secured.

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TECHNIQUE

In the course of this work several fixing reagents have been tried with varying degrees of success. Of these, Kleinenberg's picrosulphuric mixture has proved entirely satisfactory in most cases, but the best results have been obtained from the fluid used by Cameron and known as the Bles fluid; it is made as follows:—

70 % alcohol	90 parts
Glacial acetic acid	3 “
Commercial formalin	7 “

The embryos remained in this for one week and were then transferred to 70% alcohol.

When needed, the eyes were dissected out, cut in halves by a vertical section through the optical axis, and placed in 90 % alcohol for three hours, followed by 95 % alcohol for from six to twelve hours according to size. They were then cleared in cedar oil and finally imbedded in paraffin, being passed through two paraffin baths of one and three hours each, kept at a temperature of 53° C.

All sections were made with a Bausch and Lomb sliding microtome and mounted in the usual way. All were stained on the slide.

In most cases two different staining methods were used in each stage of development for the sake of comparison. These were a 33 % aqueous solution of Delafield's hæmatoxylin followed by an alcoholic solution of eosin, and an iron-alum preparation described by Cameron.

This second method gave entire satisfaction in every respect when modified by the subsequent use of eosin. The slide was first placed in a 4 % aqueous solution of iron-alum, the violet-tinted crystals, and allowed to remain ten minutes. This treatment acts as a mordant of course. It was then thoroughly washed in tap-water, dipped in a saturated aqueous solution of hæmatoxylin for ten minutes, and again washed in water. This left the sections jet black. The slide was then placed once more in the iron-alum solution and carefully watched until the sections were of a light purple tint. They were then rinsed in water and

examined under the microscope. If over-stained they were bleached a little longer in the iron-alum, if not stained enough the hæmatoxylin was repeated. The process has the advantage that it admits of absolute control. The slide was next placed in an alcoholic solution of eosin for about fifteen seconds and the excess of stain washed out in alcohol. An oil-immersion lens is absolutely essential for making out the details of retinal development.

EARLIER STAGES OF RETINAL DEVELOPMENT

After the primary optic vesicle has invaginated to form the secondary optic vesicle or optic cup, as shown in Fig. 1, it is readily seen that the invaginated portion, the earliest stage in the development of the retina, and the uninvaginated portion, which is continuous with it and is to become the pigment layer, consist of nuclei essentially similar in structure, with more or less granular protoplasm about them,—the two layers differing in thickness only. Karyokinesis at this stage takes place at the margins only of the optic cup, in both the retinal and the pigment layers.

In the earliest stage in which the retina as such is to be identified, its structure consists of nuclei suspended in cytoplasm without cell

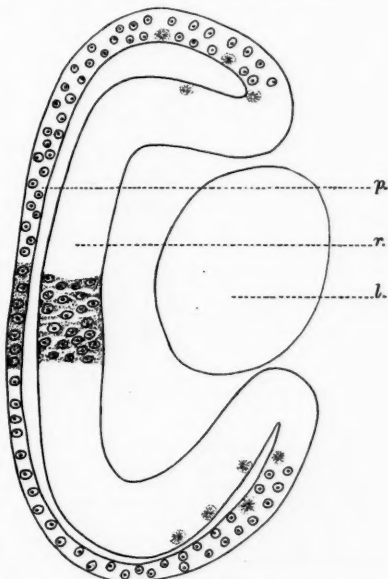


FIG. 1.—Section through the entire optic cup of a 64 hours' embryo showing relative distribution of the nuclei in the pigment layer and the retina; the mitotic figures indicate the only points at which karyokinesis takes place at this stage of development. $\times 220$. *l.*, lens; *p.*, pigment layer; *r.*, retina.

walls, *i. e.*, it is a syncytium whose outer and inner extremities form the external and internal limiting membranes. This is in accord with the conclusion of Bernard (:00). Early writers described it as made up of discrete cells, while Cameron goes to the opposite extreme and maintains that it consists of nuclei with absolutely no cytoplasm at all. Cytoplasm there certainly is in the chick at this stage if a cytoplasmic stain is used, but it

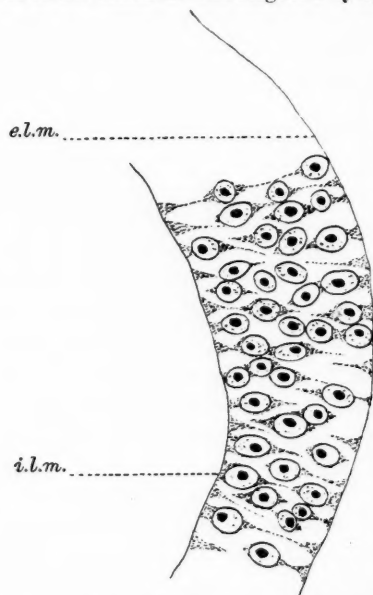


FIG. 2.—Section through a portion of the retina of a 56 hours' embryo. Each nucleus is provided with cytoplasm at its inner and outer ends. There is no cell division going on at this point in the retina at this stage. $\times 810$. *e. l. m.*, external limiting membrane; *i. l. m.*, inner limiting membrane.

is almost impossible to demonstrate it with a nuclear stain alone. It is difficult, however, to determine just what or how much cytoplasm is to be associated with each nucleus since cell walls are absent. The nuclei are evidently all alike except for slight differences in shape, some being elliptical and some circular in outline; this may be due to their being cut in different diameters. The first measure 7.29μ by 4.38μ , while the second are 5.83μ in diameter. This is as large as any retinal nuclei ever become.

Although no structural difference is apparent, there is, however, an intrinsic difference in these nuclei.

Those next the external limiting membrane have the power of division, while the others have not. These then may be called the row of germinal nuclei, which at this early stage are not dividing except at the junction of the retina with the pigment layer, but division begins immediately after the complete formation of the optic cup, so that karyokinetic figures are found from margin to margin until the beginning of differentiation of the retinal layers.

The dividing nucleus is surrounded by a clear, fluid-filled space several times as large as the other nuclei. Its outline, though formed by the surrounding protoplasm, is so pronounced as to simulate closely the appearance of an enveloping membrane. This is well shown in Fig. 5.¹ In the one in the center the plane of the section passes through the long axis of the spindle, while in

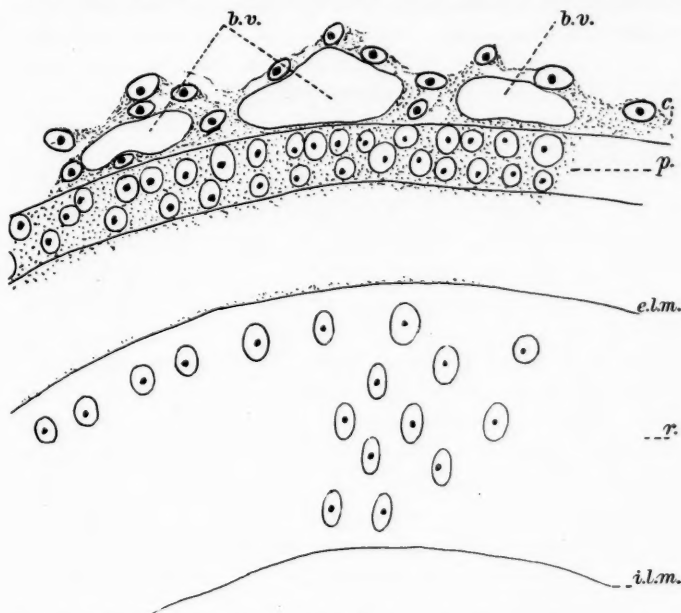


FIG. 3.—From a section of the eye of an 84 hours' embryo showing the numerous blood vessels in the choroid in close contact with the pigment layer, which here consists of two layers of nuclei embedded in a common cytoplasmic mass with no pigment granules. The wide separation of the external limiting membrane from the pigment layer is artificial. $\times 810$. *b. v.*, blood vessel; *c.*, choroid; *e. l. m.*, external limiting membrane; *i. l. m.*, inner limiting membrane; *p.*, pigment layer; *r.*, retina.

the others it cuts through or parallel with the equator. Thus it is seen that the plane of division is always perpendicular to the external limiting membrane. No exceptions to this rule have

¹ All figures are from chick embryos and were drawn with the Abbé camera lucida to the magnification indicated in each case; in some figures the details were filled in with a higher magnifying power.

been observed. After each division into two, one nucleus is left behind to contribute one additional row to the thickness of the retina while the other grows to its original size and divides again. Thus the external limiting membrane is continually moving outward the width of a nucleus with each successive generation of germinal nuclei. The fate of the nuclei thus left behind will be considered in connection with the various retinal layers.

Differentiation begins at the time the majority of germinal

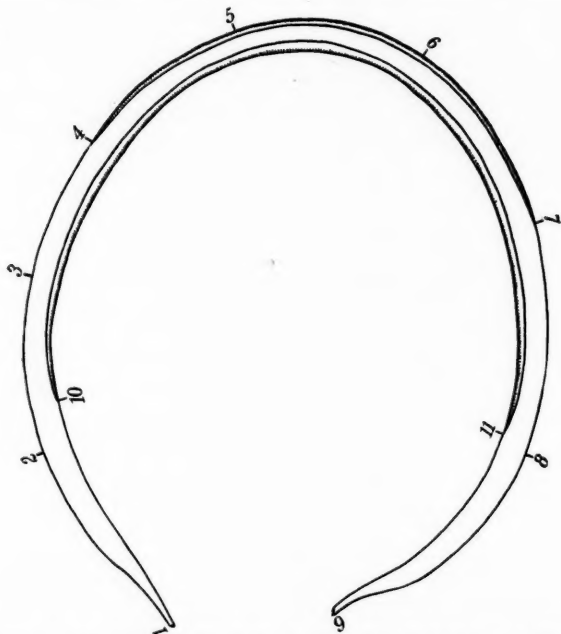


FIG. 4.—Outline drawing of a section of the entire retina of a $7\frac{1}{2}$ days' embryo. The layer of rods and cones and the outer reticular layer extend from IV to VII. The ganglion-cell layer and the inner reticular layer extend from X to XI. In the layer of germinal cells the numbers of nuclei in a dividing stage are as follows: from I to II, 82; from II to III, 47; from III to IV, 32; from IV to V, 17; from V to VI, 5; from VI to VII, 23; from VII to VIII, 56; from VIII to IX, 80. $\times 19.5$.

nuclei at the center of the retinal cup cease to divide, that is, at the end of the period of most rapid growth. Commencing thus at the center it gradually encroaches upon the territory of

the undifferentiated margins. In this way every section contains in its various parts all the preceding stages through which it has passed. For instance a segment near the margin of a ten days' retina would have attained the same degree of development as a segment through the center of the retinal cup from a younger eye. Hence in the discussion of development in this paper it is always the most highly developed portion of the retina, the center, on which all conclusions are based, and not the parts nearer the margin, which invariably represent an earlier stage.

In the growth of the retina as a whole there are three well defined periods: (1) the period of cell-multiplication, (2) the period of readjustment, (3) the period of final differentiation. The first, which extends from the second to the eighth day, is characterized by a tremendous increase in the number of nuclei and consequently in a rapid growth in the size and thickness of the whole retina, which at the end of this stage has attained its maximum width of 195μ . During the succeeding period of readjustment, from the eighth to the tenth day, there is still a rapid growth at the margins, but at the center of the retinal cup the number of nuclei is henceforth practically fixed, and the principal change is that of redistribution or readjustment into layers. Incidental to this there is a sudden decrease in width to 150μ , undoubtedly due to a stretching out of the surface area. The stage of differentiation, extending from this time to the end of incubation, is marked by the growth of cytoplasmic processes and by a gradual increase to 180μ in the thickness of the retina.

THE GANGLION-CELL LAYER

The ganglion-cell layer is the first to appear with the beginning of the period of readjustment, as shown in Fig. 6. It consists at first of three rows of nuclei which are marked off from the others by the commencement of the inner reticular layer. As the surface area of the retina increases, these nuclei, whose number of course remains the same,¹ gradually fall into line, beginning at the center

¹ In a 7½ days' embryo a single dividing nucleus was found in this layer, the only exception in the entire series studied.

of the retinal cup and thence radiating outwards on every side toward the margins, until at the end of this period the layer comes to be composed of a single phalanx of nuclei (Fig. 7). This readjustment takes place in the direction of the internal limiting membrane as is shown by the fact that there is no corresponding increase in the width of the nerve-fiber layer. Thus in its development the ganglion-cell layer actually decreases in width from 28.6μ to 10.4μ .

Part of the nuclei of this layer are the same nuclei that were seen in the early retina immediately after the formation of the optic cup (Fig. 1), and the remainder are the first nuclei to be formed by the division of the germinal nuclei. All are of the same size as those found in the early undifferentiated condition; that is to say, after division each grows to the size of the parent nucleus, a fact also true of the amacrine or horizontal nuclei. At

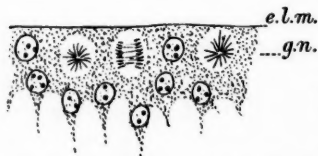


FIG. 5.—Germinal nuclei in process of division,—from the retina of a $6\frac{1}{2}$ days' embryo. All the nuclei are imbedded in a mass of granular cytoplasm, and in each case the cleavage plane is at right angles to the external limiting membrane. $\times 1500$. *e. l. m.*, external limiting membrane; *g. n.*, germinal nuclear layer.

the advent of the third stage of growth, with its attendant increase in the amount of cytoplasm, these cells become multipolar and gradually approach nearer and nearer the condition of the adult retina.

THE INNER NUCLEAR LAYER

The inner nuclear layer, which is by far the largest and most conspicuous of all, has its beginning in the fourteen successive generations of nuclei immediately following the production of those which are eventually to become the ganglion cells. Fig. 12 shows this layer in the process of formation and Fig. 13 gives the appearance three fourths of a day later. It does not become a complete layer by itself until the beginning of the period of readjustment when the outer reticular layer appears and separates it from the future external nuclear layer; but long before this, differentiation has already taken place.

In this layer the nuclei of the first generation become the inner horizontal cells while the nuclei of the last generation become the outer horizontal cells. In both cases, as mentioned before, these nuclei after division grow to the size of their immediate ancestors, the early germinal nuclei. This, however, is not true of the inter-

mediate generations. Here each successive phalanx fails to attain quite the size of the one preceding, so that when the process is complete we get the effect of a gradation of nuclei apparent in Fig. 15, where they range in size from 5.83μ to 4.38μ in diameter.

During the first two periods of growth the nuclei of this layer, which measure 7.29μ by 2.92μ on an average, are all extremely elliptical in outline, with the long axis at right angles to the limiting membranes. When examined with a low magnifying power they appear sharply pointed at the ends, and Bernard (:04) has figured them thus in his Plate 29, Fig. 25. But when studied with the oil immersion these nuclei are seen to be elliptical and bounded by a very distinct membrane which is rounded at the ends. They present very much the appearance

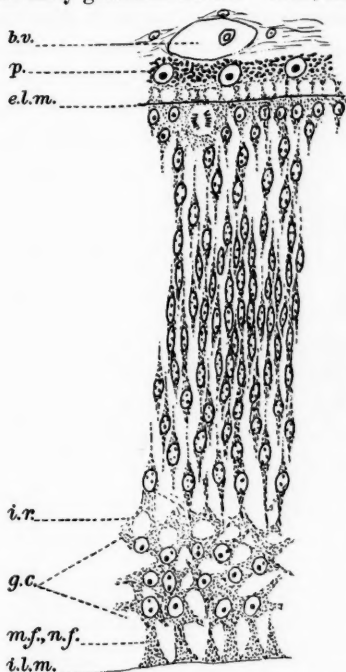


FIG. 6.—Section through the retina of a 7½ days' embryo. The ganglion-cell layer here consists of three layers of nuclei and the inner reticular layer has just begun to form. Nuclei are still dividing in the germinal layer, and the pigment layer is connected with the external limiting membrane by cytoplasmic strands. $\times 440$. *b. v.*, blood vessel; *e. l. m.*, external limiting membrane; *g. c.*, ganglion-cell layer; *i. l. m.*, inner limiting membrane; *i. r.*, inner reticular layer; *m. f.*, radial fibers of Müller; *n. f.*, nerve-fiber layer; *p.*, pigment layer.

of having been pulled outward toward the layer of germinal nuclei, for the cytoplasm about them streams from each pole in the direction

of the limiting membranes. Some of these nuclei, especially those near the middle of the layer, eventually become supporting cells or fibers of Müller. This is well shown in Fig. 12. Up to the end of the period of readjustment the chromatic substance of all retinal nuclei is scattered about in the nucleus as several granules; later, there is a single large, clearly defined chromatic mass. This condition appears to be true of other embryonic tissues as will be seen by the figure, but it is especially evident in these elliptical nuclei of the inner nuclear layer.

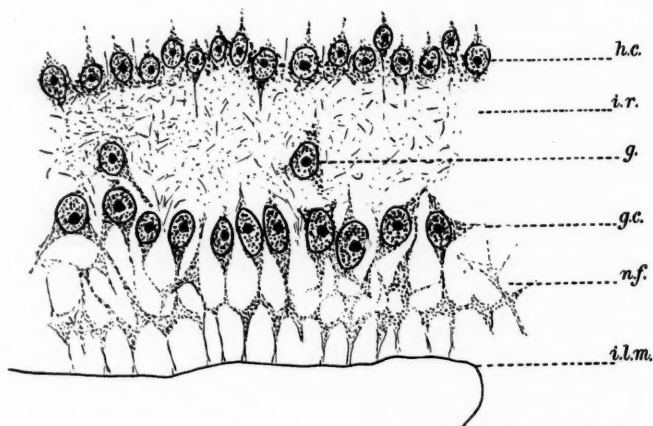


FIG. 7.—Portion of the retina of a 10 days' embryo. The ganglion-cell layer now consists of two layers of nuclei. The inner reticular layer is well differentiated and the adjacent nuclei of the inner nuclear layer will develop chiefly into horizontal cells. $\times 810$. *g.*, ganglion cell; *g. c.*, ganglion-cell layer; *h. c.*, horizontal cells or amacrine; *i. l. m.*, inner limiting membrane; *i. r.*, inner reticular layer; *n. f.*, nerve-fiber layer.

To account for the enormous increase in the number of these nuclei in so short a period two explanations have been advanced: the theory of migration and the theory of direct division; neither of these appears to us probable. The first is advanced by Bernard (:00-:04). He states that in order to account for this rapid increase in numbers "we have to assume a stream of nuclei from the undifferentiated edges of the retina towards the base of the cup." In another place in the same paper he asks the question: "Where does the middle nuclear layer get its supply of nuclei to furnish

the outer nuclear layer?" Our work on the chick demonstrates clearly that the outer nuclear layer is not derived from the inner nuclear layer in any sense of the word. Each layer is first laid down by successive generations of nuclei from within outward as Fig. 12 shows. As before stated this process is followed by a later readjustment in each layer, but not by migration from one layer to another. As for Cameron's theory of direct division there is absolutely no evidence that such a process takes place in the chick. Even at the center of the retinal cup mitotic division does not wholly cease until nearly all the rods and cones have reached an advanced stage of development.

From the time the outer reticular layer begins to appear at the end of the first period of growth no more nuclei are added to the inner nuclear layer. It has then attained its maximum thickness of

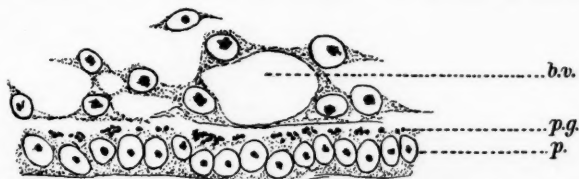


FIG. 8.—An 88 hours' embryo, in which pigment granules appear in the outer portion of the pigment-layer cells; the nuclei of this layer are closely packed together. $\times 810$. *b. v.*, blood vessel; *p.*, pigment layer; *p. g.*, pigment granules.

111.8μ . The nuclei are all crowded very closely together, this being especially true of the half of the layer nearer the external limiting membrane. Then begins the period of readjustment, during which the layer diminishes in thickness to 65μ . With the stretching out in area of the whole retina and its consequent restoration of equilibrium or equalization of tension, if we may so express it, the nuclei become more loosely arranged and gradually assume the circular outline, Figs. 13 and 15. The number of phalanges, or rows of nuclei, which was at first fourteen, has now decreased to eight, for there has been a gradual closing up of the ranks in the direction of the external limiting membrane, made evident by the corresponding increase in the width of the inner reticular layer.

In the final stage of differentiation there is little change in this

layer except for a slight decrease in thickness from $65\ \mu$ to $44.2\ \mu$. The nuclei stain more deeply with the iron-alum hæmatoxylin, and all are spherical except those of the supporting cells or fibers of Müller, while the nuclei of the horizontal cells are readily distinguished by their clearer texture. The cytoplasm of the layer remains the same in amount and appearance as at the beginning.

THE RETICULAR LAYERS

The reticular layers are purely cytoplasmic in both origin and structure, there being no evidence to the effect that nuclei have anything to do with their formation. Each retinal nucleus, except in mitosis, is always enveloped in an intact nuclear membrane, and there are never appearances that might suggest the extrusion of nuclear substance or in the strict sense of the word the protrusion of processes of any kind. To be sure, the cyto-

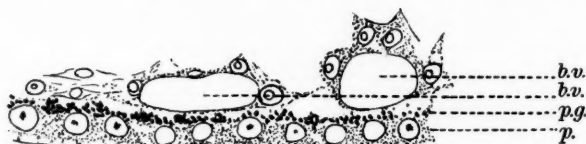


FIG. 9.—A 7 days' embryo; the nuclei of the pigment layer are more widely separated from each other; the pigment granules are more numerous and still entirely on the outer side of these nuclei. $\times 810$. *b. v.*, blood vessel; *p.*, pigment layer; *p. g.*, pigment granules.

plasmic processes of the bordering nuclei eventually extend into these layers to varying depths, but there is no ground for the assumption that such cytoplasm is of nuclear origin as Cameron believes is the case in the frog.

The inner reticular layer, which is the first of these to form, begins to appear at about the middle of the period of cell multiplication. It starts as a narrow protoplasmic rift between the third phalanx of the early ganglion-cell layer and the first generation of nuclei in the future inner nuclear layer (Fig. 6). This rift gradually widens, a little in the direction of the ganglion-cell layer, but chiefly toward the inner nuclear layer as these two layers develop. Viewed as a whole the layer has in section a crescent-shaped outline, and as it develops the pointed edges of

the crescent encroach more and more upon the undifferentiated margins, as seen in Fig. 4.

The rate of development of this layer is fairly uniform from the time of its first appearance to the end of incubation. At the commencement of the period of readjustment it has attained a width of $13\ \mu$, which has increased to $18.2\ \mu$ at its close. As will be remembered, it is during this time that the ganglion-cell nuclei fall into line, hence some of these stragglers are still to be seen lingering behind in this layer (Fig. 7). These are the nuclei which Löwe ('78) and Falchi ('87) found it so difficult to account for. From the beginning of the stage of differentiation

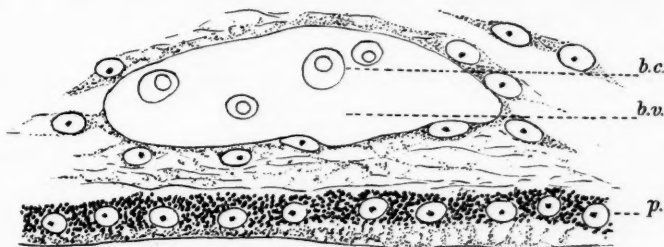


FIG. 10.— An 84 days' embryo in which the pigment granules now fill the cytoplasm between the nuclei but do not yet occupy the cytoplasm between the external limiting membrane and these nuclei. $\times 810$. *b. c.*, blood cell; *b. v.*, blood vessel; *p.*, pigment layer.

onwards there is a constant increase in width up to $44.2\ \mu$ which is the final thickness of the inner nuclear layer.

Up to the stage of completed development the structure of this layer is practically homogeneous throughout, but as differentiation proceeds, vacuoles appear next the ganglion-cell layer so that the appearance is like that in Fig. 15. Later the processes from the ganglion cells and the cytoplasmic strands from nuclei of the inner nuclear layer can be traced to varying depths, while the fibers of Müller extend perpendicularly across the layer from the internal limiting membrane to the membrane of Henle.

The outer reticular layer begins to develop four or five days later than the inner and toward the close of the period of cell multiplication. Viewed as a whole it presents in section the same crescentic appearance, but the horns of the crescent extend into

the undifferentiated region only half as far as those of the inner reticular layer (Fig. 4). Its width never increases but remains at 5.2μ , though the boundaries are not so clearly defined at first and some straggling nuclei of the inner nuclear layer are still to be

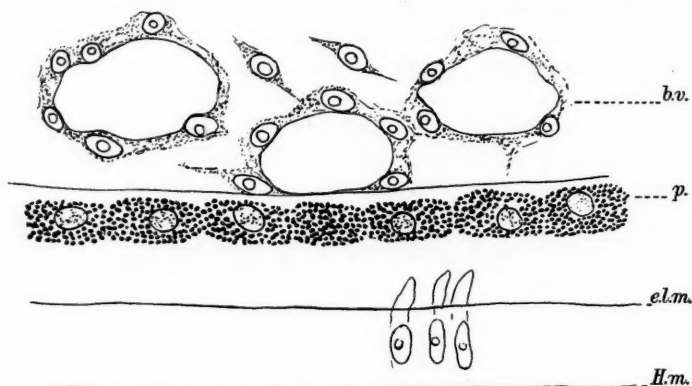


FIG. 11.—A $16\frac{1}{2}$ days' embryo showing the cytoplasm of the pigment layer completely filled with pigment granules. $\times 810$. *b. v.*, blood vessel; *e. l. m.*, external limiting membrane; *H. m.*, membrane of Henle; *p.*, pigment layer.

found in it up to the beginning of the stage of differentiation. At this stage the membrane of Henle is formed by the flattening of the inner ends of the rod and cone cells against the cytoplasm of the horizontal cells and against the ends of the fibers of Müller and of the processes from the inner nuclear layer (Fig. 13).

THE PIGMENT LAYER

The retina and the pigment layer, having as they do a common origin, develop in physical contact from margin to margin, and perhaps have an even more intimate connection, for the pigment layer probably plays an important rôle in the transfer of nutritive fluids to the multiplying nuclei and growing processes of the retina.

The pigment layer consists at first of two rows of closely packed nuclei, each 5.83μ in diameter and surrounded by protoplasm which completely fills all the remaining space between the bounding membranes. The appearance is much like that suggested

by Fig. 3. It is a significant fact that even at this early stage there are always numerous large blood vessels in the choroid tissue just outside the pigment layer.

It will be noticed in Fig. 1 that growth of the pigment layer is

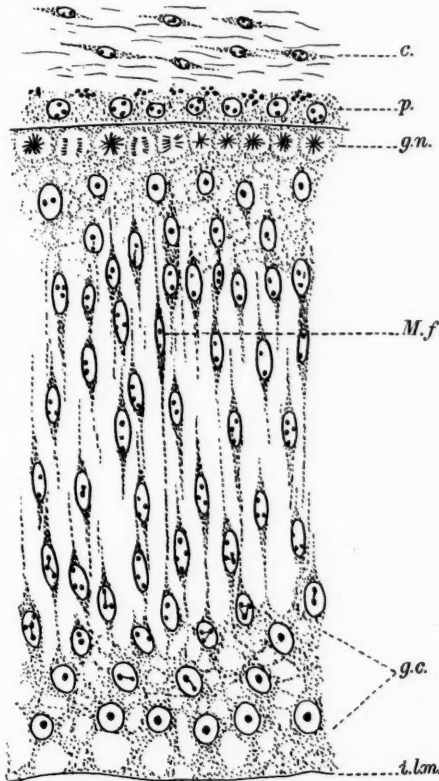


FIG. 12.—Section through the retina of a 7 days' embryo. The three layers of nuclei which will later become the ganglion-cell layer can be identified, as well as the bipolar cells of the inner nuclear layer, and the nucleus of a fiber of Müller is very distinct. Every nucleus of the germinal layer shows mitotic figures, the plane of division in each case being at right angles to the external limiting membrane; these nuclei are all imbedded in granular cytoplasm. x 810. 'c., choroid; g. c., ganglion-cell layer; g. n., germinal nuclear layer; i. l. m., inner limiting membrane; m. f., radial fibers of Müller; p., pigment layer.

at the margins and that even as early as two and two thirds days the surface area at the center of the cup has stretched out to such

an extent that the nuclei here have fallen into line so that the layer consists of a single row of nuclei. The condition at the margin of the optic cup remains the same as long as the eye continues to increase in size. Hence the row of actively dividing nuclei is always relatively short compared with that of the retina of which it is a direct continuation. After division the resulting

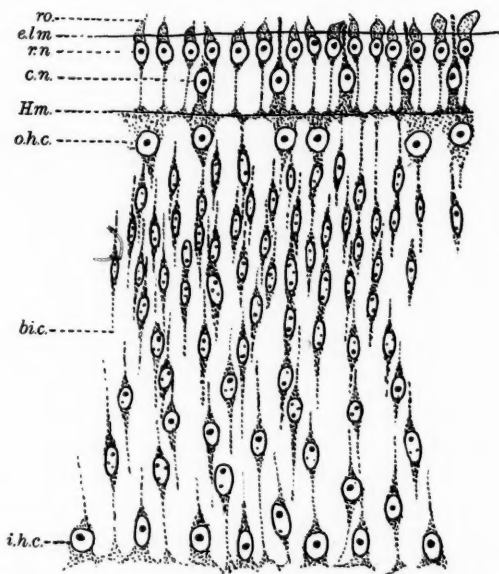


FIG. 13.—The retina of a 10½ days' embryo showing the structures outside of the inner reticular layer. In the inner nuclear layer can be distinguished the inner horizontal cells, the bipolar cells, the nuclei of the fibers of Müller and the outer horizontal cells. The outer reticular layer is forming, the membrane of Henle is distinct, and the outer nuclear layer shows the nuclei of the cones and of the rods in two layers. The cones appear as rather broad projections beyond the external limiting membrane and the cones as narrow cytoplasmic processes. x 810. *bi. c.*, bipolar cell; *c. n.*, cone nuclei; *e. l. m.*, external limiting membrane; *H. m.*, membrane of Henle; *i. h. c.*, inner horizontal cells; *o. h. c.*, outer horizontal cells; *ro.*, rods; *r. n.*, rod nuclei.

nuclei invariably grow to the size of the original nucleus, so there is never any apparent diminution in their size.

Pigment commences to form as early as three and two thirds days. Contrary to the statement which Cameron makes for the

frog, the granules begin to appear in the chick on the side of the layer away from the retina and in the protoplasm between the nuclei, which shows them to be of cytoplasmic origin (Figs. 8 and 12). Cameron says that in the frog they appear first on the side adjoining the retina. As development proceeds and the nuclei become farther apart these granules gradually fill all the cytoplasm of the pigment layer on the side farthest from the retina (Fig. 9). It will also be noticed that at the same time vacuoles

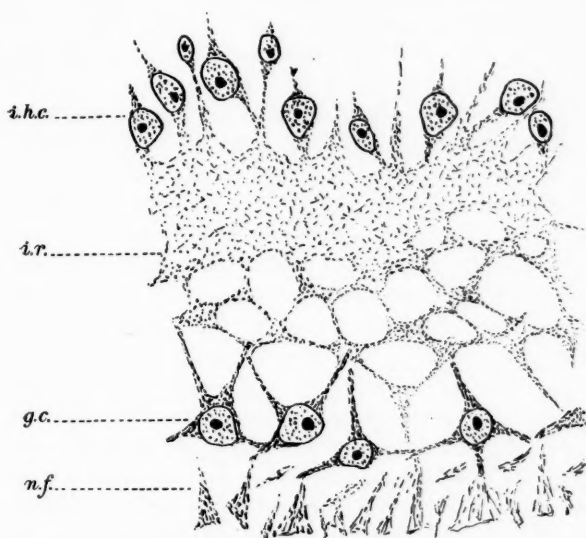


FIG. 14.—Inner portion of the retina of a 16½ days' embryo. The cells of the ganglion-cell layer now lie practically in a single plane. The inner reticular layer shows the large meshwork of its inner portion and the finer structure of its outer portion. x 810. *g. c.*, ganglion-cell layer; *i. h. c.*, inner horizontal cells; *i. r.*, inner reticular layer; *n. f.*, nerve-fiber layer.

begin to appear in the undifferentiated cytoplasm invariably present between the pigment layer and the external limiting membrane of the retina (Figs. 6 and 10). This cytoplasm is very minute in amount at an early stage of development and later increases greatly, taking the form of strands which are the beginnings of the future rods and cones and of the cytoplasmic streamers which finally develop from the pigment layer and extend inward

between them. Meanwhile the cytoplasm about the nuclei becomes differentiated to such an extent that by sixteen and one third days the layer is seen to be composed of clearly defined cells each completely filled with pigment granules (Fig. 11). Later all finer structure is entirely obliterated by the pigment, but no granules are ever found normally outside their enveloping cytoplasm. The significance of these facts in the development of the retina is seen in connection with certain theories which Bernard has elaborated. He believes that pigment is a nutritive substance which is constantly being ingested and absorbed by the growing retina. This theory had its origin in Miss Huie's article on *Drosera*, in which she has succeeded in establishing the fact of an intracellular digestion. Bernard goes so far as to describe streams of absorbed pigment stretching through the inner nuclear layer and forming the fibers of Müller. Cameron has accepted this theory and applied it in his study on the amphibian retina. The nuclei, he believes, put forth an unformed ferment or enzyme under the action of which the pigment granules are rendered available for the metabolism of the cell. In this way the rod and cone vesicles grow by successive digestions.

Before the theory is accepted, however, it must be shown that pigment is actually a food substance and not as generally supposed a waste product. The theory must be harmonized, too, with the fact that pigment granules are extremely resistant to the action of all known ferments or digesting fluids as Cameron himself states. A further objection to the theory lies in the fact that in the chick these granules first form on the side of the pigment layer away from the retina, so that the rods begin to develop before there is any pigment in their vicinity. If they are able to begin to grow without it, is it not at least possible that they might continue to develop without it? Further, pigment is never found outside the protoplasm of the pigment cell; none ever appears in the retina, or even in contact with the rods and cones during their development. Besides, may not the mediation of a third substance and in such an unavailable form be entirely superfluous, for cannot the rods and cones obtain nutritive material for their growth direct from the numerous blood vessels just outside the pigment layer?

THE OUTER NUCLEAR LAYER

The outer nuclear layer, which forms during the period of readjustment, consists of two rows of nuclei. The one first laid down and adjoining the membrane of Henle is the layer of cone nuclei,

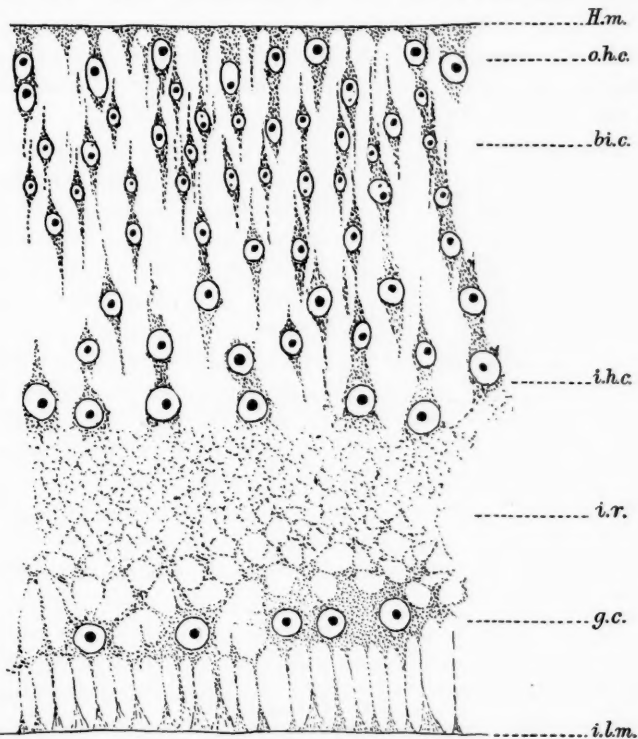


FIG. 15.—Retina of a 16½ days' embryo from the internal limiting membrane to the membrane of Henle. The expanded inner ends of the radial fibers of Müller are evident. The large nuclei of the inner and outer horizontal cells appear in the inner nuclear layer, the remaining nuclei in this layer belonging to bipolar cells and to the fibers of Müller. $\times 810$. *bi. c.*, bipolar cell; *g. c.*, ganglion-cell layer; *H. m.*, membrane of Henle; *i. h. c.*, inner horizontal cells; *i. l. m.*, inner limiting membrane; *i. r.*, inner reticular layer; *o. h. c.*, outer horizontal cells.

which are fewer in number and more scattered in position (Fig. 13). The other, which borders on the external limiting membrane,

represents the last product of the division of the germinal nuclei. In fact, division among them does not wholly cease until the rods of their immediate neighbors have attained a high degree of development. Thus the rod nuclei are the youngest in the retina. All measure 4.38μ in diameter, which is the regular size of the germinal nuclei after the first half of the first period of growth. They suffer no diminution in size with the development of the rods and cones, and least of all do they receive any accessions to their number by a migration of nuclei from the inner nuclear layer.

Long before division has ceased in the row of rod nuclei, in fact as soon as the outer nuclear layer begins to appear at the center of the retinal cup, the rudiments of the future rods and cones can be made out in the shape of cytoplasmic threads or strands between the pigment layer and the external limiting membrane. The rods and cones are clearly of cytoplasmic origin. This cytoplasm slowly increases in amount so that at the beginning

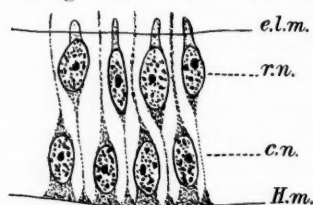


FIG. 16.— The development of the rods and cones in a 10 days' embryo. The rod-body is distinctly granular; the cone-body appears as a narrow cytoplasmic thread. $\times 1500$. *c. n.*, cone nuclei; *e. l. m.*, external limiting membrane; *H. m.*, membrane of Henle; *r. n.*, rod nuclei.

of the stage of differentiation the appearance is like that shown in Fig. 13. It will be noticed that a fragment of the original protoplasmic thread still tips the ends of some of the rod rudiments, while the base of the rod appears drawn out into a finely attenuated stalk whose inner extremity flattens against the membrane of Henle. The base of the cone is shorter and much broader (Fig. 16). As development proceeds, little or no change takes place in the outer nuclear layer strictly so called except that the nuclei toward the close of the period of differentiation stain more deeply with the iron-alum hæmatoxylin. This is true of all retinal nuclei.

The cytoplasm of the rods, which at first is evenly granular and homogeneous throughout, gradually increases in amount and assumes more and more the conical appearance presented in Fig. 17. About the middle of the period of differentiation, a clear

unstaining vesicle appears at the tip or outer segment and persists in the same size and shape during the remainder of the development of the rod. There is no evidence that it is of nuclear origin in the chick, although Cameron describes it as such in the frog. The cytoplasm between this vesicle and the rod nucleus gradually elongates as development proceeds but without any appreciable increase in amount since at the same time the diameter diminishes, and eventually a conical cap of protoplasm develops on the distal end so that the unstaining vesicle appears like a fluid-filled vacuole imbedded in the rod about a fourth the way from the finely tapering point.

An interesting statement in this connection is made by Bernard, and repeated in more elaborate form by Cameron, to the effect that the nuclei of the rods tend to become protruded to varying degrees beyond the external limiting membrane. This certainly does not seem to be the case in the chick, although at first glance the appearance is strikingly in accord with such a statement. In the base of many of the rods and just outside the external limiting membrane appears a structure that might easily pass for a nucleus. The object

proved a puzzle for a time, but with more careful study its explanation became clear. It was found that all the rods do not stand exactly perpendicular to the external limiting membrane, but many of them are bent over at various angles with it; and consequently these structures that look so much like nuclei are the truncated ends of other rods that once pointed toward the observer. By

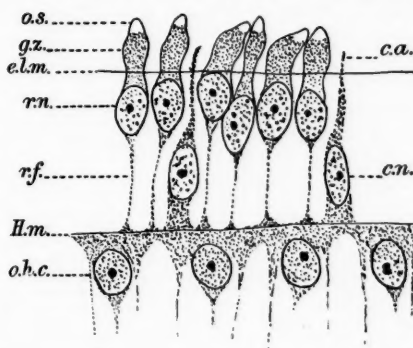


FIG. 17.— The developing rods and cones in an 11 days' embryo. The rods now show a clear outer segment and a granular inner zone. The cones are essentially the same as in the preceding figure. $\times 1500$. *c. a.*, cone anlage; *c. n.*, cone nuclei; *e. l. m.*, external limiting membrane; *g. z.*, granular zone of rod; *H. m.*, membrane of Henle; *o. h. c.*, outer horizontal cells; *o. s.*, outer segment of rod; *r. f.*, rod fiber; *r. n.*, rod nuclei.

focusing down on them the remainder of the stump can be traced to its own nucleus. Hence the rod nucleus invariably retains its early position wholly inside the external limiting membrane. We have been unable to find such effects in the chick as Cameron figures in the frog in his Pl. 51, Figs. 24 and 29, where the nucleus forms a distinct projection beyond the limiting membrane.

VARIATIONS IN THE RELATIVE RATE OF DEVELOPMENT

In the development of the retina the time of appearance of the different elements is not absolutely fixed. An eye at ten days may have reached the same degree of development as another at twelve, or again it may be no further advanced than some that are two days younger. In the same retina it might be expected that the state of development of one layer would bear some definite relation to that of the others. But this is not the case. When the ganglion-cell layer has reached the stage shown in Fig. 6, the inner nuclear layer may appear as shown in that figure, or it may be more or less highly developed. Very frequently the inner nuclear layer reaches a very advanced stage before any cytoplasmic changes in the outer nuclear layer have begun to appear at all. On the other hand the rods and cones may be developing rapidly while the other layers are still in the earlier stages. The fact has been mentioned before that when the majority of the rods are in an advanced stage of development others are found beside them whose nuclei have just ceased dividing and whose rudiments have not begun to develop at all. Hence from the appearance of a part it is impossible to predict the stage of development of any other, for there appears to be no definite developmental ratio that might serve as a criterion. The drawings in each case are from the more typical representatives, and give the appearance most frequent at the specified age.

SUMMARY AND CONCLUSIONS

1. The retina consists at first of a syncytium.
2. Most of these nuclei eventually go to form the ganglion-cell layer; those next the external limiting membrane become the germinal nuclei.

3. Only one row of germinal nuclei has the power of division.
4. There are three well defined periods of growth: (a) the period of cell multiplication, second to eighth day; (b) the period of readjustment, eighth to tenth day; (c) the period of final differentiation, tenth day to end of incubation.
5. Up to the end of the first period the retina grows from within outward by the deposition of an additional row of nuclei with each successive generation.
6. After this, karyokinetic figures are found only at the margins.
7. Differentiation begins at the center of the retinal cup and gradually spreads in every direction toward the growing margins.
8. Between the center of the optic cup and the growing margin of any given retina are represented all the different stages through which it has passed; the nearer the margin, the younger the stage.
9. The ganglion-cell layer consists at first of three rows of nuclei.
10. These fall into line in the direction of the internal limiting membrane so as eventually to form but one layer.
11. In the inner nuclear layer differentiation into horizontal cells, fibers of Müller, and bipolar cells takes place *pari passu* with the formation of these nuclei.
12. This layer consists at first of about fourteen generations of nuclei.
13. With the exception of the horizontal cells each successive generation fails to attain quite the size of the one preceding.
14. As development proceeds the number of rows of nuclei decreases from fourteen to eight by a closing up of the ranks in the direction of the external limiting membrane.
15. Up to the end of the period of readjustment the nuclei of this layer are elliptical in outline with the long axis at right angles to the external limiting membrane.
16. Later these nuclei become circular in outline.
17. The reticular layers are cytoplasmic in both origin and structure.
18. The pigment layer is a direct continuation of the retina.
19. Like the retina its early structure is also a syncytium.
20. The nuclei at first are in two rows which early become arranged as one with the stretching out of the surface area.

21. Active growth is restricted to the margins of the pigment layers and continues as long as the eye increases in size.
22. Nuclei of this layer are always of the same size as those found in the early undifferentiated condition.
23. Pigment granules first form on the side of the layer away from the retina and in the protoplasm between the nuclei.
24. These granules are never normally found outside the cytoplasm of the pigment cell.
25. There is no evidence that pigment is a food substance.
26. The numerous large blood vessels always present in the choroid coat next the pigment layer may furnish the nutritive material for the development of the retina.
27. The outer nuclear layer represents the last two generations from the division of the germinal nuclei.
28. The rod nuclei are the youngest in the retina.
29. They are more numerous than the cone nuclei, and division among them does not wholly cease until the rods of their immediate neighbors have attained a high degree of development.
30. The rods and cones have their origin in undifferentiated cytoplasm.
31. There is no evidence that any part of the rod or cone is of nuclear origin.
32. The nuclei of the rods and cones retain their early position wholly within the external limiting membrane and do not tend to become protruded to varying degrees beyond it, as has been recorded for other animals.
33. In the development of the retina there is no fixed time for the appearance of the different elements.

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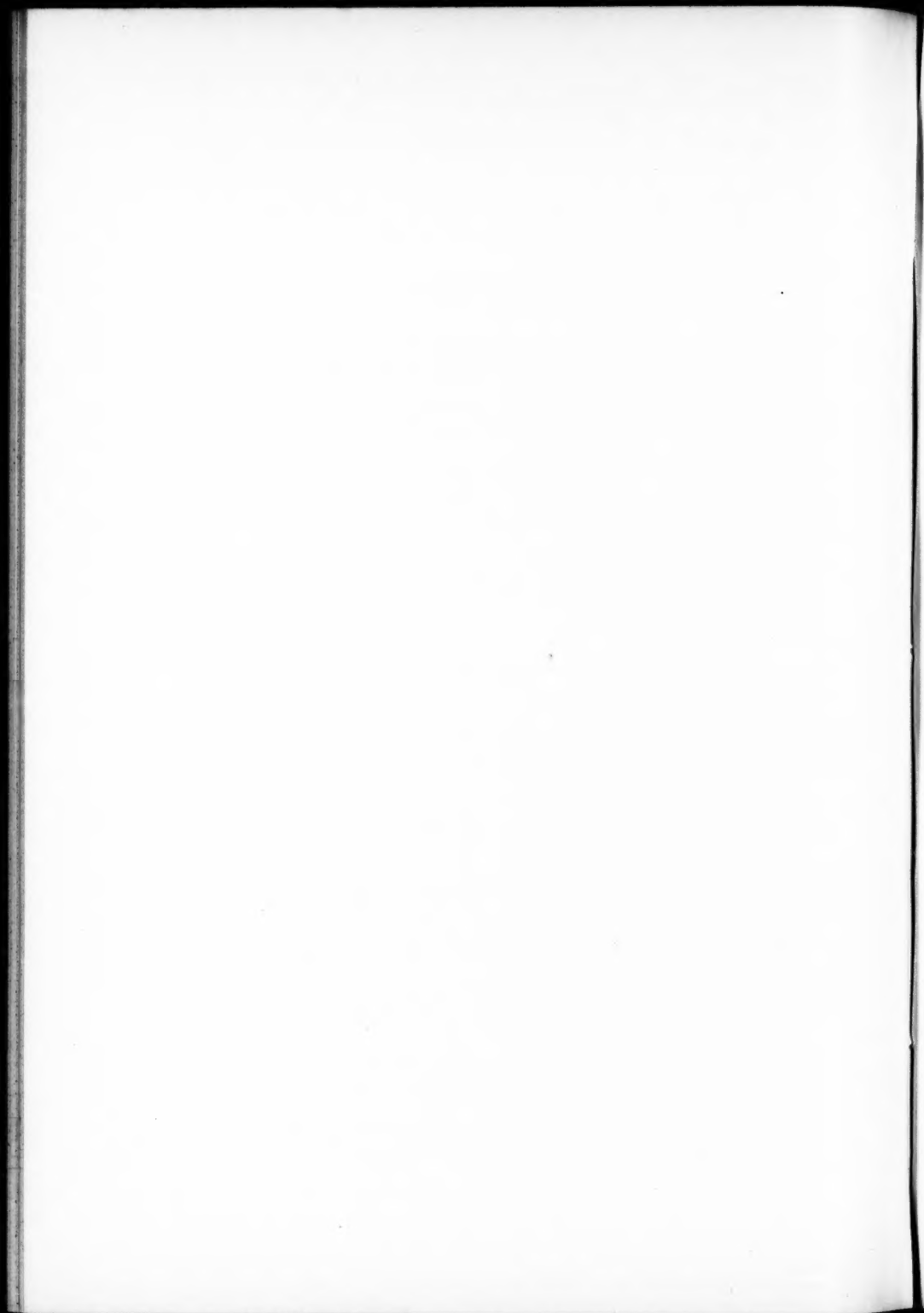
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NOTES ON MARINE COPEPODA OF RHODE ISLAND

LEONARD WORCESTER WILLIAMS

WORK upon the non-parasitic Copepoda of America is very fragmentary. In recent years the papers of Wheeler, of Giesbrecht, and of Herdman, Thompson, and Scott record a relatively small number of forms from what is apparently an extremely rich fauna. Miss Rathbun's check-list of the Crustacea of New England records twelve free-swimming marine Copepoda. None of these, however, is reported in the waters of Rhode Island.

This list records twenty-six free-swimming Copepoda, one parasitic form, and a metanauplius of a parasitic copepod. Of the free-swimming Copepoda eleven have been reported previously: eight by Herdman, Thompson, and Scott from the Gulf of St. Lawrence and six by Wheeler from the Wood's Hole region. We also describe three new species.

The material upon which this paper is based was obtained in Narragansett Bay. Winter collections were made above Rocky Point and summer collections near Wickford, and in Charlestown Pond during the entire summer. The latter is situated in southern Rhode Island and is a large shallow inlet (six miles long by one broad) from the Atlantic. It is slightly brackish but the copepod fauna is much the same as that of the bay.

I am indebted to Dr. A. D. Mead of Brown University for the use of preserved material collected at Wickford by the Rhode Island Commission of Inland Fisheries; to Professor C. B. Wilson for kind assistance; and to Mr. Samuel Henshaw for the use of books from the Museum of Comparative Zoölogy at Harvard.

Type specimens of the new species have been deposited in the museum of the Boston Society of Natural History.

***Calanus finmarchicus* (Gunnerus)**

1765. *Monoculus finmarchicus* Gunnerus.

1863. *Cetochilus helgolandicus* Claus.

- 1864. *Calanus finmarchicus* Boeck.
- 1878. *Calanus finmarchicus* Brady.
- 1892. *Calanus finmarchicus* Giesbrecht.
- 1903. *Calanus finmarchicus* Sars.

This is a species widely distributed in the North Atlantic and Arctic Oceans, having been taken by Nansen's expedition above 85° north latitude. It has been twice reported from American waters, by Thompson and Scott ('98) and by Wheeler (:00). It appeared abundantly in tows taken in Narragansett Bay in January but was found at no other time. The specimens agree with those taken by Wheeler in lacking the marked concavity of the inner border of the basal joint of the fifth pair of legs of the female.

***Pseudocalanus elongatus* (Boeck)**

- 1864. *Clausia elongata* Boeck.
- 1878. *Pseudocalanus elongatus* Brady.
- 1892. *Pseudocalanus elongatus* Giesbrecht.
- 1898. *Pseudocalanus elongatus* Thompson and Scott.
- 1903. *Pseudocalanus elongatus* Sars.

Narragansett Bay, January, February. This is a decidedly northern form, its southern European limit being the northern coast of France.

***Centropages hamatus* (Lilljeborg)**

- 1853. *Ichthyophorba hamata* Lilljeborg.
- 1863. *Ichthyophorba angustata* Claus.
- 1864. *Centropages hamatus* Boeck.
- 1892. *Centropages hamatus* Giesbrecht.
- 1898. *Centropages hamatus* Thompson and Scott.
- 1900. *Centropages hamatus* Wheeler.
- 1903. *Centropages hamatus* Sars.

Narragansett Bay, January, February. Wickford, summer.

PSEUDODIAPTOMUS Herrick

- 1884. *Pseudodiaptomus* C. L. Herrick.
- 1890. *Schmackeria* Poppe and J. Richard.
- 1894. *Heterocalanus* T. Scott.
- 1894. *Weismannella* Dahl.

Head separated from, or fused with the first thoracic segment; fourth and fifth segments of the thorax fused (or not). Abdomen of the female 4- or 3-jointed. Furca at least two and a half times as long as broad, with six setae. First antenna 20- to 22-jointed. Terminal section of the grasping antenna of the male usually 2-jointed. The second antenna with a long outer ramus of two to four joints. Outer ramus of mandible 3- or 4-jointed; inner ramus inconspicuously 2-jointed, its second joint curved outward strongly. The first joint of the basipodite of the second maxilla is divided into two sections. Basipodite of the maxilliped short and strong, inner ramus 4- or 5-jointed, some of its bristles branched. The inner and outer rami of the first to fourth leg 3-jointed, terminal joint of the outer ramus with two outer spines and a terminal spine serrated externally. The inner ramus of the fifth limb of the female rudimentary or absent, outer branch 2- or 3-jointed. Inner ramus of the left fifth limb of male usually rudimentary, rarely absent or transformed into a grasping organ; outer ramus 2-jointed, occasionally reduced to a claw-shaped process of the basipodite. Inner ramus of the right fifth limb rudimentary or lacking; outer ramus 2- or 3-jointed with an end claw. One or two egg sacs.

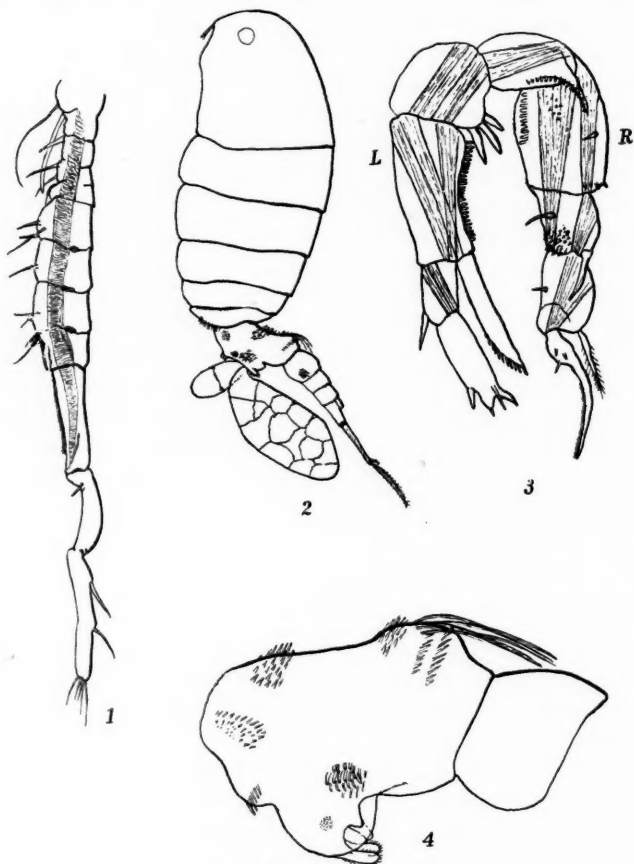
***Pseudodiaptomus coronatus* n. sp.**

Figs. 1-7

The generic description must be modified slightly to admit this species: the fourth and fifth thoracic segments are not fused and the seventh and eighth segments of the first antenna are not completely fused and if they are considered separate the first antenna is 23-jointed. In other respects the species agrees with the generic description. The last thoracic segment (Fig. 2) is rounded posteriorly and is naked in the male and haired in the female. The fourth thoracic segment is spined in the female and naked in the male. Abdomen of male 5-jointed; of female 4-jointed. Almost all bristles of the feet and furca are jointed some distance from their bases (Fig. 7).

Female.—First segment of abdomen much swollen with spines.

and bristles arranged asymmetrically, and with a pair of spatulate flaps (Figs. 4 and 5) extending over the genital aperture. The bristles of the left side of the genital segment in both areas are



Pseudodiaptomus coronatus

FIG. 1.—Right antenna of male. x 150.

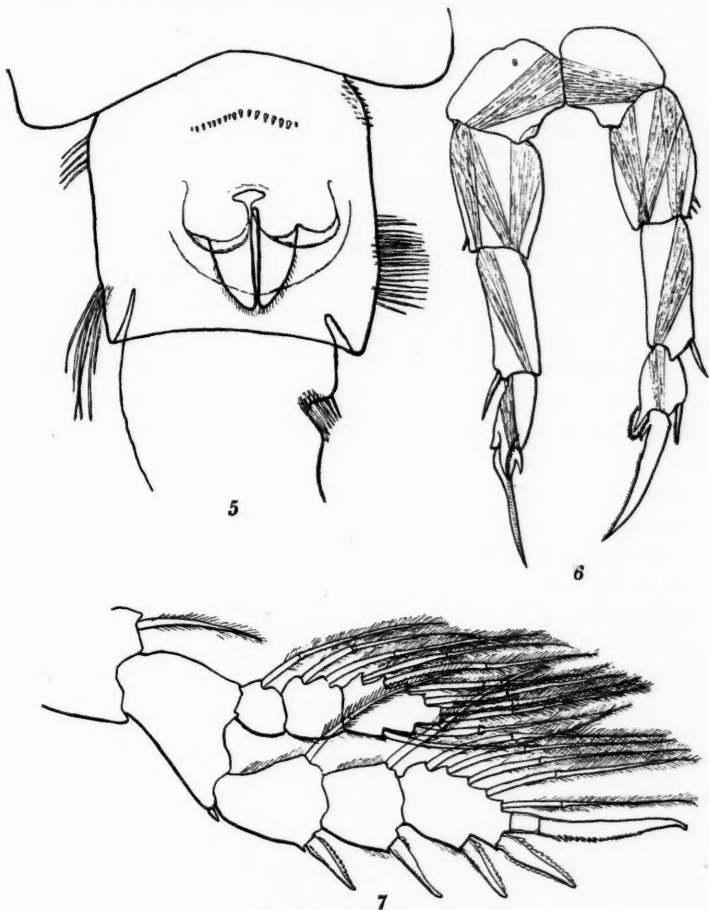
FIG. 2.—Lateral view of female. x 50.

FIG. 3.—Fifth limbs of male, posterior surface. x 130.

FIG. 4.—Left side of the genital segment of female. x 175.

respectively much longer than those of the right side. A small tuft of very long soft bristles near the posterior edge of the dorsal

surface projects almost across the second segment. The left side of the second segment of the abdomen has a small depression filled with heavy bristles while the right side is convex and bears a few spines (below the middle and so not shown in the drawing). The last segment has a crown of spines, on the posterior edge. The furca is slightly asymmetrical and each ramus is five times as long



Pseudodiaptomus coronatus

FIG. 5.—Genital segment of female, ventral surface. x 175.

FIG. 6.—Fifth limbs of female, posterior surface. x 175.

FIG. 7.—Third swimming foot, female. x 280.

as broad and has long delicate bristles on the inner edge and shorter and stronger bristles on the outer edge. The fifth limbs are alike (Fig. 6) and 4-jointed. The terminal joint is prolonged at the inner angle into a toothed lamella and has a spine at the outer angle. The terminal claw is toothed along its inner (concave) border and has a naked lamella on the inner side at base. One large and one (right) small egg case.

Male.—Abdomen long and slender. First joint bristled along the upper part of its posterior edge and with a semicircle of bristles on the lower surface. The upper part of the hinder edge of the second joint and the entire posterior edge of the third, fourth, and fifth joints have a crown of triangular spikes. The furca is three times as long as broad and lacks marginal bristles. The right fifth limb (Fig. 3) has no inner ramus; outer ramus 2-jointed with a terminal claw. First joint of basipodite has a slender curved process coarsely toothed along its inner edge, the second joint and the first joint of the outer ramus are toothed inside. The second joint of the inner ramus has a bristled spine and a curved terminal claw toothed on the inner edge and swollen at base. The left fifth limb biramous. The first joint of the basipodite has a cluster of three or four broad radiating spines. The second joint has coarse teeth on its inner edge. The inner ramus is a blade toothed along the distal half of its curved outer edge. The outer ramus is 2-jointed; the first joint has an outer terminal spine and the second joint ends irregularly in four spines. The right antenna (Fig. 1) has a terminal section of two joints and has the third joint from the end toothed along its anterior edge.

Length of female 1.5 mm.; of male 1.2 mm.

Narragansett Bay and Charlestown Pond.

***Temora longicornis* (O. F. Müller)**

1785. *Cyclops longicornis* Müller.

1850. *Temora finmarchica* Baird.

1865. *Temora longicornis* Boeck.

1878. *Temora longicornis* Brady.

1892. *Temora longicornis* Giesbrecht.

1898. *Temora longicornis* Thompson and Scott.

1900. *Temora longicornis* Wheeler.

1903. *Temora longicornis* Sars.

Narragansett Bay, January, February.

EURYTEMORA Giesbrecht

1881. *Eurytemora* Giesbrecht.1881. *Temorella* Claus.

Body moderately slender, rostrum with small, soft lappets. Fifth thoracic segment free, often expanded laterally. Abdomen slender, genital segment slightly protruding downward. Furca elongated, symmetrical. Anterior antenna in female comparatively short, scarcely longer than the cephalothorax, 24-jointed. Right antenna of male geniculate, terminal portion of two (three?) joints. Posterior antenna with outer ramus longer than inner and 7-jointed. Mouthparts similar to those of *Temora* except that the posterior maxillipeds are shorter and stouter. Inner ramus of the first leg 1-jointed, of the second to the fourth, 2-jointed. Fifth legs of female 4-jointed, penultimate joint produced on the inside into a strong, pointed process; terminal joint small. Fifth legs of male 4- or 5-jointed, about equal; terminal joint of right leg claw-shaped, of left, spatulate or dilated.

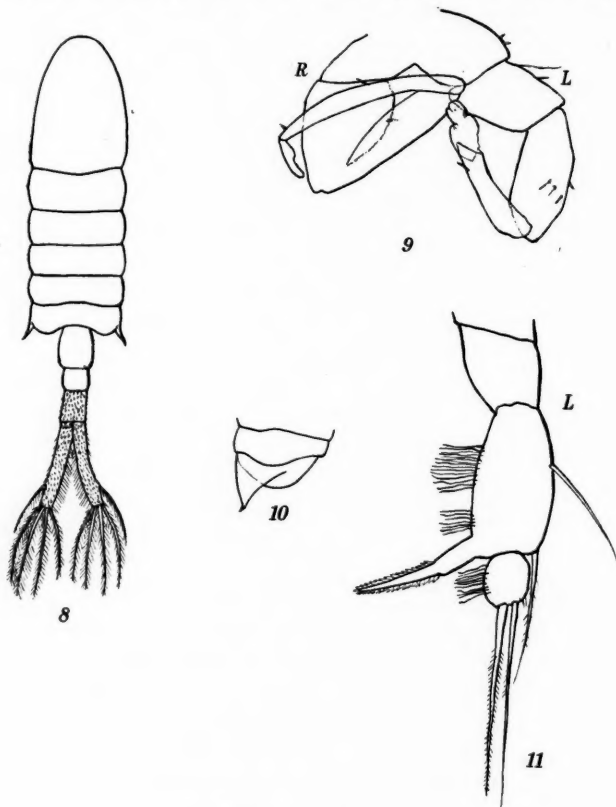
Marine, brackish, and fresh water.

***Eurytemora americana* n. sp.**

Figs. 8-11

Female.—The lateral angles of the last segment of the thorax (Figs. 8 and 10) are drawn out into conspicuous triangular wings which are distinct from the rounded posterior surfaces of the segment. The wing arises from the lower two thirds of the outer side of the segment and its upper edge is slightly concave, and its lower edge slightly convex. In lateral view it forms, with the hinder edge of the segment, an S-shaped outline. The abdomen is 3-jointed; the genital segment is evenly rounded at the sides and above but projects below; the genital opening is covered by a broad, cordate flap. The upper surface of the anal segment and furca is covered with short, strong spines. The furcal arm is eight times as long as broad, curved outward a little, and slightly tapering. The furcal setae, except the dorsal ones, are as long as the furca, coarse, and swollen at the base. The dorsal seta is short and

jointed near the base. First antenna as long as the trunk and strong. The fifth limb (Fig. 11) is similar to that of *E. lacustris* but the penultimate joint is longer, and its inner process is more slender and is finely bristled on both edges. The terminal joint



Eurytemora americana

FIG. 8.—Dorsal view of female. x 40.

FIG. 9.—Fifth limbs of male, anterior surface. x 350.

FIG. 10.—Left side of the fourth and fifth segments of female.

FIG. 11.—Left fifth limb of female, anterior surface. x 350.

bears two setæ of nearly equal length, but the inner one is heavier and is more distinctly bristled. The inner edges of the last and next to the last joints bear long, slender bristles. Eggs light green.

Male.—Lateral angles of the last thoracic segment rounded.

Abdomen slender, 5-jointed. Anal segment with few spines and furca without spines on the upper surface. Furca six times as long as broad, inner edge with long slender bristles. Furcal setae as in the female, therefore longer than the furca. The left first antenna is relatively longer than in the female, reaching to the second segment of the abdomen. Right first antenna as in *E. herdmani*, i. e., about as long as left antenna, very heavy, and with the terminal portion composed of two long segments and a minute terminal segment; seventeenth and eighteenth joints with a comb-like ridge; nineteenth joint with a notch on the anterior side at base and two toothed ridges beyond the notch. The right fifth limb (Fig. 9) is 5-jointed, the last two not being fused and the next to the last slightly swollen at base. Left fifth limb 5-jointed, the last joint separated from the fourth joint by an oblique hinge and ending in three lobes, each with a spine upon its apex.

The first to fourth limbs of both sexes are very similar to those of *E. velox*.

Length of ♀, 1.8 mm.; cephalothorax, 1.07 mm.

Length of ♂, 0.9 mm.; cephalothorax, 0.68 mm.

Narragansett Bay, January to April; Charlestown Pond, summer.

Males and females of this species were brought through the last molt to sexual maturity. The males happened to molt earlier than the females, and for some days each carried a spermatophore by its stalk in the fifth limb, another spermatophore being almost or quite fully formed within the body.

***Eurytemora hirunoides* (Nordquist)**

1888. *Temorella affinis* var. *hirunoides* Nordquist.

1898. *Eurytemora affinis* var. *hirunoides* Giesbrecht and Schmeil.

1903. *Eurytemora hiruno* des Sars.

Narragansett Bay, January; Charlestown Pond, July.

The specimens agree very closely with Sars' description and plates of the Norwegian form.

***Eurytemora herdmani* Thompson and Scott**

1898. *Eurytemora herdmani* Thompson and Scott.

1898. *Eurytemora herdmani* Giesbrecht and Schmeil.

Narragansett Bay at Wickford. This species has been reported previously from the Gulf of St. Lawrence only.

Acartia tonsa Dana

- 1849. *Acartia tonsa* Dana.
- 1892. *Acartia tonsa* Giesbrecht.
- 1900. *Acartia tonsa* Wheeler.

Charlestown Pond. Abundant throughout the summer. The predominant copepod in the tow. The fifth limbs of the female are symmetrical in all the specimens examined and not as in Wheeler's figure.

Acartia clausii Giesbrecht

- 1892. *Acartia clausii* Giesbrecht.
- 1895. *Acartia clausii* Thompson.
- 1898. *Acartia clausii* Thompson and Scott.
- 1903. *Acartia clausi* Sars.

Narragansett Bay. Abundant in January and February. This species has a very wide distribution, occurring in the Atlantic, Mediterranean, the Black Sea, and the Gulf of Guinea (Scott, '94). Thompson and Scott found it in the Gulf of St. Lawrence but this is the first report of its occurrence in New England waters.

TORTANUS Giesbrecht

- 1883. *Corynura* Brady.
- 1892. *Corynura* Giesbrecht.
- 1898. *Tortanus* Giesbrecht and Schmeil.

Head without lateral hooks; eye large, without cuticular lens; no rostrum; a horseshoe-shaped fringed lamella in front of the upper lip. Thorax symmetrical, last segment separate or fused with the preceding. Abdomen of female often laterally compressed, 2- or 3-jointed. First antenna like that of *Acartia*, but the middle section of the gripping antenna is thicker. Two rami of the second antenna of nearly equal length; terminal segment of outer ramus rudimentary. Two rami of the mandible inserted at the end of the elongated second joint of the basipodite. First maxilla consisting of the first joint of the basipodite and the two much bristled

inner border lobes. Proximal lobes of the second maxilla much reduced. Maxillipeds 3-jointed. Inner ramus of first to fourth swimming feet 2-jointed (or the first with 3 joints). Fifth limb with one ramus in female, 2- or 3-jointed in the male, similar to *Acartia*, but stronger.

***Tortanus setacaudatus* n. sp.**

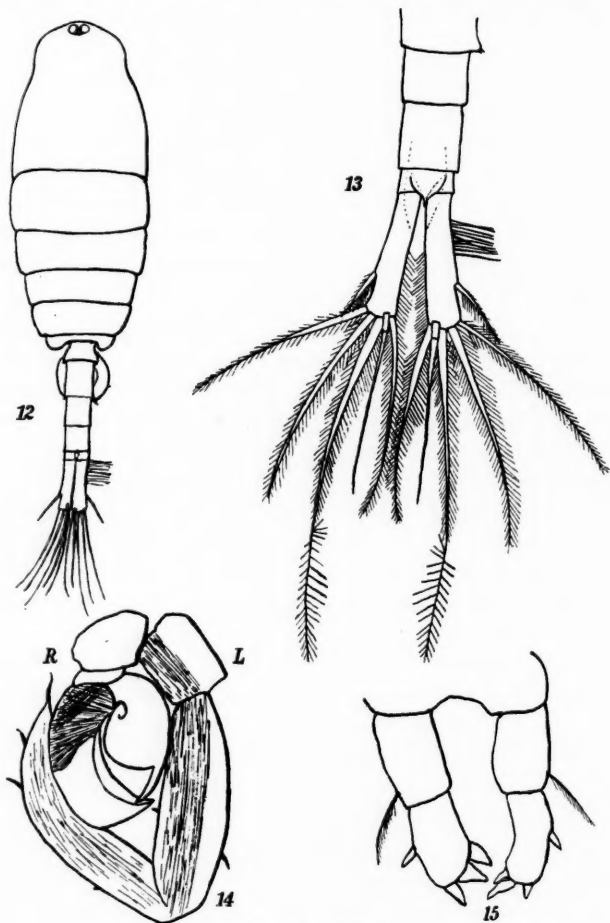
Figs. 12-15

Last thoracic segment free. First antenna long, 17-jointed, reaching beyond the end of the furca by one or two joints. The maxillipeds are extraordinarily large and are carried in a very characteristic manner, *i. e.*, horizontally and at right angles to the sagittal axis, so that the long curved, bristled, and toothed setæ point forward. Abdomen and furca long.

Female.—Abdomen 3-jointed, slightly compressed laterally. The left arm of the furca is sharply compressed laterally at its base; otherwise the furca and abdomen are symmetrical. Genital segment enlarged, slightly rounded with a rounded prominence on each side of the genital opening. Anal segment with an acute strong dorsal spine. Each arm of the furca is fringed with soft bristles along the distal half of its inner edge, and has the full number of setæ. Five of these are plumose and unjointed, and one, the dorsal seta, projects upward from the plane of the others and is naked and jointed near the base. The third seta from the inside is longer than the majority and its projecting end bears stiff, long bristles which are more scattered than the others, and are attached at different angles. Feet of the fifth pair 2-jointed, alike (Fig. 15). First joint oblong with a plumose bristle on the outer edge near the end; terminal joint slightly narrower than the first, with four short, broad spines, one near the middle of the outer edge and three at the apex.

Male.—Gripping antenna powerful; distal section of two joints, middle section of six joints; of these, the second and fourth have a seta at the distal end, and the fifth and sixth and the first joint beyond the hinge have each a ridge which is finely toothed and ends in a spine. Abdomen of five joints (Fig. 12). The right side of the edge of the second joint is enlarged into a tubercle

which bears one or two minute spines. The anal segment is very short and has a dorsal spine similar to that of the female (Fig. 13). The right arm of the furca is slightly broader and longer than the left and bears upon its outer edge near the middle a tuft of from



Tortanus setacaudatus

FIG. 12.—Dorsal surface of male. x 75.

FIG. 13.—Dorsal surface of male abdomen. x 172.

FIG. 14.—Fifth feet of male, anterior surface. x 272.

FIG. 15.—Fifth feet of male, posterior surface. x 395.

12 to 20 stiff, slender bristles which form a conspicuous brush. The furcal setae and the hairs on the inner edge of the furca are as in the female. Left fifth limb 3-jointed, more than twice the length of the right (Fig. 14). Basal joint nearly as broad as long; the second joint long, with one or more bristles on the inner and outer edges; distal joint arcuate, pointed, nearly as long as the other two, and with three recurved bristles on the outer and one on the inner edge. Right fifth limb is 3-jointed, the last two joints forming a heavy pincer; the second joint is spoon-shaped and receives a curved spine borne on the lower (anterior) side of the end of the swollen terminal joint.

Length of female 1.40 mm., of male 0.94 mm.

Abundant in Narragansett Bay and Charlestown Pond.

This is the second species of *Tortanus* to be described from the eastern coast of North America. *T. discaudatus* Thompson and Scott ('98) from the Gulf of St. Lawrence is very similar to this species. *T. bumpusii* Wheeler (1900) was found in Vineyard Sound and is apparently *T. discaudatus*.

***Oithona plumifera* Baird**

1843. *Oithona plumifera* Baird.

1892. *Oithona plumifera* Giesbrecht.

1900. *Oithona plumifera* Wheeler.

Narragansett Bay, February.

***Oithona similis* Claus**

1866. *Oithona similis* Claus.

1892. *Oithona similis* Giesbrecht.

1900. *Oithona similis* Wheeler.

Narragansett Bay at Wickford, June.

***Longipedia coronata* Claus**

1863. *Longipedia coronata* Claus.

1880. *Longipedia coronata* Brady.

1898. *Longipedia coronata* Thompson and Scott.

1903. *Longipedia coronata* Sars.

Narragansett Bay and Charlestown Pond, summer. We have found no American record for this species.

Ectinosoma normani T. and A. Scott

1896. *Ectinosoma normani* T. and A. Scott.

1903. *Ectinosoma normani* Sars.

Charlestown Pond, summer. A species recorded from Norway, Scotland, and Ceylon.

Ectinosoma curticorne Boeck

1872. *Ectinosoma curticorne* Boeck.

1895. *Ectinosoma curticorne* Thompson.

1903. *Ectinosoma curticorne* Sars.

Charlestown Pond. One of the most common copepods in July and August. It has been previously reported from Norway, Scotland, and Spitzbergen.

Microsetella norvegica (Boeck)

1864. *Setella norvegica* Boeck.

1873. *Ectinosoma atlanticum* Brady and Robertson.

1890. *Ectinosoma atlanticum* Brady.

1892. *Microsetella atlantica* Giesbrecht.

1898. *Ectinosoma atlanticum* Thompson and Scott.

1903. *Microsetella norvegica* Sars.

Narragansett Bay, March. This species is cosmopolitan, with a wide distribution in the Atlantic Ocean and occurs in the Arctic, the Pacific, the Mediterranean, the Red Sea, and the Indian Ocean.

Tachidius littoralis Poppe

1881. *Tachidius littoralis* Poppe.

1895. *Tachidius littoralis* Thompson.

Narragansett Bay. Abundant in March and April.

Tachidius brevicornis (Müller)

1776. *Cyclops brevicornis* Müller.

1853. *Tachidius brevicornis* Lilljeborg.

1880. *Tachidius brevicornis* Brady.

1882. *Tachidius discipes* Giesbrecht.

Charlestown Pond, summer.

Parategastes sphaericus (Claus)

1863. *Amymone sphaerica* Claus.
1866. *Amymone sphaerica* Claus.
1880. *Amymone sphaerica* Brady.
1903. *Tegastes sphaericus* Norman.
1904. *Parategastes sphaericus* Sars.

Charlestown Pond, abundant in July. The hand of the second maxilliped in these specimens is somewhat heavier than in the European species and resembles that of *Tegastes grandimanus*. Otherwise the agreement is complete.

Diosaccus tenuicornis (Claus)

1863. *Dactylopus tenuicornis* Claus.
1872. *Diosaccus tenuicornis* Boeck.
1873. *Nitokra tenuicornis* Brady and Robertson.
1880. *Diosaccus tenuicornis* Brady.

Charlestown Pond, July.

Dactylopusia vulgaris G. O. Sars.

1850. *Canthocamptus stromii* Baird.
1863. *Dactylopus cinctus* Claus.
1880. *Dactylopus stromii* Brady.
1903. *Dactylopusia vulgaris* Sars.

Charlestown Pond, July.

Thalestris serrulata Brady

1880. *Thalestris serrulata* Brady.
1895. *Thalestris serrulata* Thompson.
1898. *Thalestris serrulata* Thompson and Scott.

One female of this somewhat rare species was taken by scraping piles at high tide at Rocky Point in Narragansett Bay. Thompson and Scott have reported it from the American coast.

Harpacticus uniremis Kröyer

1845. *Harpacticus uniremis* Kröyer.
1903. *Harpacticus uniremis* Sars.

Narragansett Bay, abundant in February, March, and April; Charlestown Pond, July. Females in egg were found in both the summer and winter tows, though the largest number of specimens in copula were taken in March and April. The species was found in great abundance in shallow water and not, as Sars reports of the Norwegian specimens, confined to depths of from twenty to a hundred fathoms.

Harpacticus chelifer (Müller)

- 1776. *Cyclops chelifer* Müller.
- 1834. *Harpacticus chelifer* Milne-Edwards.
- 1880. *Harpacticus chelifer* Brady.
- 1903. *Harpacticus chelifer* Sars.

Charlestown Pond, July.

Idya furcata (Baird)

- 1837. *Cyclops furcatus* Baird.
- 1863. *Tisbe furcata* Claus.
- 1864. *Idya furcata* Boeck.
- 1880. *Idya furcata* Brady.
- 1903. *Idya furcata* Sars.

Narragansett Bay, spring. This is a very common Norwegian copepod and is "ubiquitous in the British seas" to quote Dr. Brady. It is also found in the Mediterranean, the Red Sea, and in New Zealand.

Argulus laticauda Smith

- 1874. *Argulus laticauda* Smith.
- 1903. *Argulus laticauda* Wilson.
- 1904. *Argulus laticauda* Wilson.

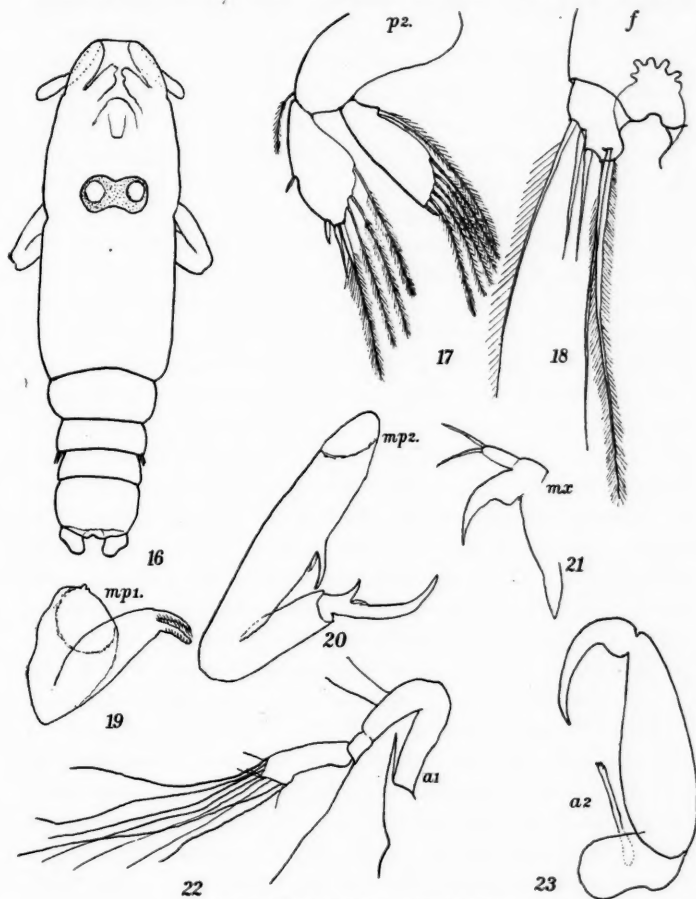
Charlestown Pond on tautog (*Tautoga onitis*).

Metanauplius of Caligus or Lepeophtheirus

Figs. 16-23

Two specimens of this metanauplius were taken near the surface, one on January 13 on the east side of the upper part of

Narragansett Bay (Crescent Park), the other a week later on the opposite side of the bay (Pawtuxet). They resemble in general the metanauplius raised from the eggs of *Caligus bonito* by C. B. Wil-



Metanauplius of Caligus or Lepeophtheirus

FIG. 16.—Dorsal view. x 123.

FIG. 17.—Second foot, left. x 345.

FIG. 18.—Left arm of furca. x 345.

FIG. 19.—Right first maxilliped. x 345.

FIG. 20.—Right second maxilliped. x 345.

FIG. 21.—Right maxilla or mandible. x 345.

FIG. 22.—Left first antenna. x 345.

FIG. 23.—Left second antenna. x 345.

son (*Proc. U. S. Nat. Mus.*, vol. 28, figs. 40-45, 1905). Professor Wilson says of my specimens it is "the first instance on record where one has been obtained in its free habitat." The capture proves his inference that the metanauplius is free-swimming. However, even the genus cannot be positively identified since Professor Wilson's metanauplius is the only one as yet recognized. (The two specimens described by Brady ('99) from Otago, New Zealand, and named provisionally *Centromma thomsoni*, are very like my specimens and must belong to the Caligidæ rather than to the Corycæidæ.)

Length 0.63 mm.; breadth 0.157 mm.

The carapace is moderately slender and is marked near the middle by a slight notch on each side (Fig. 16). In front of these notches lie the eyes, the two pairs of antennæ, the protrusive toothed proboscis, the maxilla (?), and two maxillipeds. There seems to be a groove or depression in the dorsal surface of the carapace which runs backward from the front almost to the eyes. The ruby-red eyes are fused and lie just in front of the notches of the carapace. The first antenna (Fig. 22) arises some distance from the anterior end of the carapace and passes forward to its tip, then turns backward and downward towards its origin, and finally outward. The first portion seems to consist of two joints: a basal joint which is not clearly marked off from the carapace and which bears at its outer distal angle a strong spine, and a distal joint which is about twice the length of the first. The second portion is formed of two joints: a long one which bears two bristles and a short joint whose end is drawn out on the side next the carapace (outer side) into a long bristle. The distal portion of the antenna is a single joint which seems to be held almost at right angles to the sagittal axis of the metanauplius. Its end bears ten or twelve (or more) bristles, most of which are long and all non-plumose and flaccid. The second antenna (Fig. 23) is biramous. The basal joint is short and broad, and lies just inside that of the first antenna. The inner ramus is slender and relatively short, and ends in a tuft of four or more unjointed spines. The outer ramus is 2-jointed. The proximal joint is moderately swollen at the base but tapers distally. The distal joint is a hook swollen at the base.

On each side of the mouth there is the structure represented in Fig. 21 whose identity is not clear but which probably represents the maxilla. It is a ridge which bears in front a 2-jointed appendage and ends posteriorly in a strong spine. The basal joint of the appendage is drawn out posteriorly into a curved spine, swollen at base. It is possible that this represents the outer ramus and the basal portion of the appendage. The distal joint is oval, outwardly directed, and ends in two strong bristles. The first maxilliped (Fig. 19) is 2-jointed, heavy and short. The distal joint terminates in two claws, of which the outer is bristled and the inner finely toothed or bristled. The second maxilliped (Fig. 20) is 3-jointed. The basal joint bears near the middle of its inner surface a strong, backwardly directed spine. The second joint is about one half as long as the first. The distal joint is a sickle-shaped hook with a spine at base. The mouth is supplied with a protrusible proboscis which is a truncated cone armed at the apex with a circle of inwardly directed spines. This suggests that the metanauplius is ready to attach itself to a host.

At the posterior end, the carapace bears a pair of swimming legs. The first of the free thoracic segments bears a pair of legs and the second has on each side two spines. Two segments follow, the first without appendages, and the second, the anal segment, with the short furca. The two pairs of legs are very similar. Each has a single basal joint and two 1-jointed rami. There is a feathered bristle on the tip of the outer edge of each basal joint. The outer ramus of the first pair of swimming feet has four spines, one at the outer side and three at the end, and three long feathered bristles. The inner ramus has a smooth outer edge which bears an unjointed spine at the end. The inner edge has six (or seven) long feathered bristles. The second pair of legs (Fig. 17) is similar except that the outer ramus has three spines and four bristles and the inner ramus is broader than in the first pair. Each anal lamella (Fig. 18) (ramus of the furca) is short and irregular, and bears five bristles. The outer furcal seta is plumose on the outer side and the inner seta is plumose on both edges.

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BROWN UNIVERSITY

LICHENS OF MOUNT MONADNOCK, NEW HAMPSHIRE

REGINALD HEBER HOWE, JUNIOR

MT. MONADNOCK (3166 feet), the typical representative of the monadnock type of worn-down mountain, is situated in the southeastern corner of Cheshire County, N. H., in the townships of Jaffrey and Dublin. It rises from well watered, rolling meadow and woodland country of the Transition zone, and though surrounded by several prominent hills, Gap (1900 feet) for example, it stands well isolated. The lower slopes of the mountain are covered with upland pastures and woodlots, while between the altitudes of 2000 and 3000 feet of the Sub-Canadian zone, its sides are well wooded with both coniferous and deciduous growths. Above 3000 feet the fauna and flora of its weathered, rounded, and rocky summit of resistant ledges are characteristic of the Canadian zone.

The lichens here listed were collected on April 5, 1906, about the base of the mountain on the Troy side, and on Bigelow Hill (1702 feet), and again on April 6, 1906, during one ascent to the summit of Monadnock itself.

Examples of all specimens listed are in my herbarium. For the verification of determinations of the genus *Cladonia*, and of several other specimens I am indebted to the kindness of Professor Bruce Fink of Grinnell, Iowa. To Mr. Rollin M. Gallagher I am also indebted for assistance in collecting.

1. *Ramalina calicaris fraxinea* Fr.—One specimen collected on a cherry tree, Bigelow Hill. Fertile.

2. *Ramalina calicaris fastigiata* Fr.—Common in the Transition zone. Found on cherry, elm, and on Bigelow Hill on a rock. Fertile.

3. *Ramalina calicaris canaliculata* Fr.—One specimen collected on an elm, Bigelow Hill. Fertile.

4. *Ramalina calicaris farinacea* Schaer.—One old wall had several patches on individual rocks. Transition zone. Sterile.
5. *Cetraria islandica* (L.) Ach.—Common in a reduced state on the ledges near the summit. Sterile.
6. *Cetraria ciliaris* (Ach.).—Not uncommon on pines near the base. Fertile.
7. *Cetraria lacunosa* Ach.—Common on pines on Bigelow Hill and about the base of the mountain; rare in the Sub-Canadian zone. Fertile.
8. *Cetraria oakesiana* Tuck.—Common in the Sub-Canadian zone on dead wood, yellow birch, oaks, and in one instance on rock. Sterile.
9. *Cetraria juniperina pinastri* Ach.—A few examples on a fallen spruce at timber line. Sterile.
10. *Evernia prunastri* (L.) Ach.—Common in the Transition zone, rare in the Sub-Canadian. Found growing on old roofs, stone wall, on *Parmelia perlata* on rock, and on deciduous trees. Sterile.
11. *Usnea barbata florida* Fr.—Uncommon on oaks on Bigelow Hill. Sterile.
12. *Usnea barbata florida rubiginia* Michx.—Bigelow Hill. Uncommon on oaks. A small but fairly typical specimen was collected on a rock, which proves that the coloring is not due to tannin or some other vegetable coloring matter in the bark of trees as has been suggested. Sterile.
13. *Usnea barbata ceratina* Schaer.—One untypical specimen collected on an oak on Bigelow Hill. Sterile.
14. *Alectoria jubata chalybeiformis* Ach.—A single specimen was collected on Bigelow Hill on the ground, growing with *Cladonias*.
15. *Theloschistes concolor effuse* Tuck.—Two small specimens on oak on Bigelow Hill.
16. *Parmelia perlata* (L.) Ach.—Common on rocks throughout the Transition and Sub-Canadian zone. Fertile in two instances.
17. *Parmelia cetrata* Ach.—Two examples on oak on Bigelow Hill.
18. *Parmelia crinita* Ach.—One example growing on moss on apple tree. Bigelow Hill. Sterile.

19. *Parmelia tiliacea* (Hoffm.) Floerk.—Common throughout Transition and Sub-Canadian zones. Collected on apple and yellow birch. Fertile.

20. *Parmelia borrieri rudecta* Tuck.—Common in Transition and Sub-Canadian zones. Collected on yellow birch. Sterile.

21. *Parmelia saxatalis* (L.) Fr.—Not uncommon on rock. Transition zone. Fertile.

22. *Parmelia saxatalis sulcata* Nyl.—Common in both Transition and Sub-Canadian zones, growing on trees and rock. Sterile.

23. *Parmelia physodes* (L.) Ach.—Common throughout both Transition and Sub-Canadian zones, but more common in the latter. One example fertile. Collected on trees, and rarely on rocks.

24. *Parmelia olivacea* (L.) Ach.—Common in Sub-Canadian zone on yellow birch and oak. Fertile.

25. ? *Parmelia olivacea sorediata* (Ach.) Nyl.—One specimen collected on a white pine at the base of the mountain seems referable to this form.

26. *Parmelia caperata* (L.) Ach.—Common in Transition zone, more rarely met with in the Sub-Canadian. Collected both on rocks and on trees. Sterile. When found growing vertically on rocks this species has a deceptive shredded appearance.

27. *Parmelia conspersa* (Ehrh.) Ach.—Common throughout the two lower zones growing on rocks, replaced by the following species above timber line. Fertile.

28. *Parmelia centrifuga* (L.) Ach.—Not uncommon above timber line, confined mainly to the highest ledges. One example fertile.

29. *Physcia pulverulenta leucoleiptes* Tuck.—Common in the Transition zone on apple trees. Sterile.

30. *Physcia stellaris* (L.).—Common both on rocks and trees. Fertile.

31. *Physcia stellaris aipolia* Nyl.—One example collected on a rock. Bigelow Hill. Sterile.

32. *Physcia tribacea* (Ach.) Tuck.—One example collected on rock on Bigelow Hill. Fertile.

33. *Physcia obscura endochrysea* Nyl.—Common on yellow birch in the Sub-Canadian zone. Sterile.

34. *Pyxine soreliata* Fr.—Not uncommon on beech in Sub-Canadian zone. Sterile.
35. *Umbilicaria hyperborea* Hoffm.—Found both on the top of Bigelow Hill on boulders, and on the summit ledges of Monadnock.
36. *Umbilicaria muhlenbergii* (Ach.) Tuck.—Growing on pasture rock at the base of the mountain. Fertile.
37. *Umbilicaria dillenii* Tuck.—Common on ledges in the Sub-Canadian zone.
38. *Umbilicaria pennsylvanica* Hoffm.—Several specimens were collected on ledges at about 2500 feet elevation. Fertile.
39. *Umbilicaria pustulata papulosa* Tuck.—Common on pasture rocks and on the mountain ledges nearly to the summit. Fertile.
40. *Stictia amplissima* (Scop.) Mass.—Common on yellow birch on the mountain and also on rocks on Bigelow Hill. Fertile.
41. *Stictia pulmonaria* (L.) Ach.—Common in both Transition and Sub-Canadian zones on oaks and yellow birch, and in a few instances on rocks. Sterile.
42. *Nephroma tomentosum* (Hoffm.) Koerb.—One example on rock in Sub-Canadian zone. Fertile.
43. *Nephroma lævigatum* Ach.—One example on rock, Sub-Canadian zone. Fertile.
44. (?) *Peltigera canina* (L.) Hoffm.—On ground over ledges, not uncommon. Bigelow Hill. Sterile.
45. *Pannaria lanuginosa* (Ach.) Koerb.—Common on rocks in the two lower zones. Sterile.
46. *Ephebe solida* Born.—One example on rock, Bigelow Hill. Determined through the kindness of Dr. Herbert M. Richards of Barnard College, N. Y.
47. *Leptogium tremelloides* (L. fil.) Fr.—One example on rock, Sub-Canadian zone. Sterile.
48. *Placodium vitellinum* (Ehrh.) Noeg. & Hepp.—One example on old barn, Transition zone. Fertile.
49. *Lecanora rubina* (Vill.) Ach.—Common on rock on Bigelow Hill. Fertile.
50. *Lecanora subfusca* (L.) Ach.—One example on yellow birch. Fertile.
51. *Lecanora pallescens* (L.) Schaer.—One example on yellow birch in Sub-Canadian zone. Fertile.

52. *Pertusaria velata* (Turn.) Nyl.—One example on oak. Bigelow Hill. Fertile.
53. *Stereocaulon paschale* (L.) Fr.—Common on rocks in Sub-Canadian zone. Fertile.
54. *Stereocaulon tomentosum* (Fr.) Th. Fr.—One example on rock in Sub-Canadian zone. Fertile.
55. (?) *Cladonia cariosa* (Ach.) Spreng.—One example on ground, Sub-Canadian zone. "An unusual form to be studied further."—Fink.
56. *Cladonia pyxidata* (L.) Fr.—Common, Sub-Canadian zone.
57. *Cladonia fimbriata nemoxyne* (Ach.) Coem.—Two examples, mossy ground and old stump, Sub-Canadian zone.
58. *Cladonia fimbriata coniocræa* (Floerk) Wain.—One example on ground, Sub-Canadian zone.
59. *Cladonia squamosa* Hoffm.—One example on ground, Sub-Canadian zone.
60. *Cladonia furcata* (Huds.) Fr.—Common on ground, Sub-Canadian zone.
61. *Cladonia furcata* (*racemosa* Fl. or *pinnata* (Fl.) Wain. ?) — One example on ground, Sub-Canadian zone.
62. *Cladonia rangiferina* (L.) Hoffm.—Abundant on ground in all three zones.
63. *Cladonia rangiferina sylvatica* L.—Common on ground, particularly in the two lower zones.
64. *Cladonia amaurocræa* (Fl.) Schaer. (*furcata* ?).—Common on ground between ledges in Canadian zone.
65. *Cladonia uncialis* (L.) Fr.—One example on ground, Canadian zone.
66. *Cladonia boryi* Tuck.—Common on ground in a reduced condition in Canadian zone.
67. *Cladonia* (*Cornucopoides*) *coccifera* (L.) Willd.—Common on ground in Sub-Canadian zone.
68. *Cladonia coccifera pleurota* (Fl.) Schaer.—One example on ground, Sub-Canadian zone.
69. *Cladonia bacillaris* Nyl.—One example on fallen stump on ground, Sub-Canadian zone.
70. *Cladonia cristatella* Tuck.—Common in two lower zones.
71. *Graphis scripta* Ach.—One example on beech, Sub-Canadian zone.

NOTES AND LITERATURE

BOTANY

Notes.—A monograph of Primulaceæ, by Pax and Knuth, forms Heft 22 of Engler's *Das Pflanzenreich*.

An account of a large white elm, with figures, is given by Williams in *Forest Leaves* for February.

A case of trunk-grafting of the elm is illustrated in *Sports Afield* for February.

An interesting series of Rumex illustrations, including hybrids, is being published in vol. 24 of Reichenbach's *Icones Floræ Germanicæ et Helvicæ*.

The Camus monograph of the willows of Europe has recently been completed by the issuance of a second part, with atlas, from the Lechevalier House, of Paris.

Engler revises the pothoid Araceæ in Heft 21 of *Das Pflanzenreich*.

The rediscovery of *Cypripedium fairieanum* is sketched by Barron in *The Garden Magazine* for March.

A domestically interesting Aloe, from Angola, is described by Berger in the *Journal of Botany* for February.

Foliage anatomy and its classificatory value in Festucaceæ are considered by Luerssen in Heft 63 of *Bibliotheca Botanica*.

A series of photographic illustrations of agriculturally interesting grass glumes is given by Neubauer in *Landwirtschaftliche Jahrbücher* for December 18.

Sorghum halepense, like *S. vulgare*, is said to yield hydrocyanic acid sometimes under the influence of enzymes, by Crawford, in *Bulletin no. 90, part 4*, of the Bureau of Plant Industry, U. S. Department of Agriculture.

A popular note on evergreens, with some Conifer illustrations, is published by Maynard in *Suburban Life* for February.

A reprint of the Lloyd edition of "Travels in the Interior of North America," by Maximilian, Prince of Wied (London, 1843) is being issued as volumes 22 to 24 of Thwaites' *Early Western Travels: 1748-1846* — with atlas.

An account of the forest belts of western Kansas and Nebraska, by Kellogg, forms *Bulletin no. 66*, Forest Service, of the U. S. Department of Agriculture.

An account of the wild and cultivated Amaryllidaceæ of Argentina is given by Holmberg in vol. 5 of the current series of *Anales del Museo Nacional de Buenos Aires*.

An interesting account of the macroplankton, or free-floating archeogonates and spermatophytes of the pools of Paraguay is given by Chodat in the *Bulletin de l'Herbier Boissier* of January 31.

An Enumeration of the Vascular Plants known from Surinam, Together with their Distribution and Synonymy, by Pulle, has been issued from the Brill press of Leiden.

A dichotomous key to French plants has been published by Lévêillé (Paris, Chas. Amat, 1906), in convenient pocket form.

A monograph of the Aconites of India, by Stapf, forms vol. 10, part 2, of the *Annals of the Royal Botanic Garden, Calcutta*.

The utilization of seaweeds of the United States is considered by Smith in vol. 24 of the *Bulletin of the Bureau of Fisheries*.

Mushrooms and their cultivation form the subject of a well illustrated article by McAdam in *Country Life in America* for February.

A paper on the Russulas of Madison and vicinity, by Denniston, has been separately printed from vol. 15 of the *Transactions of the Wisconsin Academy*.

A note on the poisoning of cattle in Manitoba by *Amanita muscaria* and a species of *Boletus* is published by Criddle in *The Ottawa Naturalist* for February.

A brief account of the mechanism by which *Salix*, *Cladrastis*, *Tilia*, and other woody genera discard their terminal buds in a characteristic manner, is given by Tison in *Comptes Rendus... de l'Académie des Sciences* of Paris for January 22.

Weevil-resisting characters in cotton, some of them connected with the "kelep" ant, form the subject of *Bulletin no. 88* of the Bureau of Plant Industry, U. S. Department of Agriculture, by Cook.

An account of some phases of the ecology of plants of the extreme north has recently been issued by Haglund, of Upsala.

A list of wild medicinal plants of the United States, by Alice Henkel, forms *Bulletin no. 89* of the Bureau of Plant Industry, U. S. Department of Agriculture.

The botanical treatment in the new *National Standard Dispensatory* (Lea Brothers & Co., 1905) is by Rusby.

An economic account of *Mentha piperita* and its varieties is given by Alice Henkel in *Bulletin no. 90, part 3*, of the Bureau of Plant Industry, U. S. Department of Agriculture.

An account of the Japanese lac derived from *Rhus* is given by Stevens in *The American Journal of Pharmacy* for February.

Mayer, in *Landwirtschaftliche Jahrbücher* of December 18, gives a translation of an article by Giltay on the method of teaching botany in the agricultural academy at Wageningen.

A biographic sketch of Errera, by Massart, with an excellent portrait and a list of his publications, has been issued from the Hayez press of Brussels.

An illustrated account of the Desert Botanical Laboratory at Tucson is contributed by Cannon to *Out West* for January.

The third annual issue of part M, Botany, of the *International Catalogue of Scientific Literature* was issued in September by the Royal Society of London,—the manuscript having been completed in February last. It forms an octavo volume of 909 pages.

A photographically illustrated article on soil formation, by Fletcher, is published in *Country Life in America* for January.

Pammel has distributed an interesting paper comparing certain swamp, clay, and sandstone floras,—separately printed from vol. 10 of the *Proceedings of the Davenport Academy of Sciences*.

The flora of one of the "Chouteau buttes" of Missouri is analyzed by Standley in vol. 1, part 2, of the *Bulletin of the Bradley Geological Field Station* of Drury College.

A list of additions and corrections to Fleet's list of Mt. Rainier plants is published by Piper in *Mazama* of December last.

An illustrated account of the vegetation of the Bahamas, with a list of the species so far known as occurring on them, is separately

issued by the author, Professor Coker, from Shattuck's *The Bahama Islands*, published by the Geographical Society of Baltimore.

The concluding parts of Macloske's "Flora Patagonica," forming part 5 of volume 8 of the *Reports of the Princeton University Expeditions to Patagonia, 1896-1899*, have recently been issued.

A paper on the alpine flora of northern Argentina, by R. E. Fries, is published as the opening number of series 4, vol. 1, of the *Nova Acta R. Societatis Scientiarum Upsaliensis*.

The third of Merrill's papers on "New or Noteworthy Philippine Plants," and a paper on the source of Manila "elemi," form no. 29 of the publications of the *Bureau of Government Laboratories*, of Manila.

The *Flora of Tropical Africa*, under the editorship of Sir William T. Thiselton-Dyer, reaches into Convolvulaceæ in the recently issued vol. 4, sect. 2, part 1.

An account of the botany of northwestern New South Wales is given by Turner in vol. 30 of the *Proceedings of the Linnean Society* of that country.

A colored plate of *Sarracenia flava* accompanies an article on the genus in *Flora and Sylva* for November.

An illustrated account of garden Sarracenias, by Vollbracht, is published in the *Wiener Illustrierte Garten-Zeitung* for December.

An illustrated monograph of the Uromyces forms of Bauhinia is published by Westergren in no. 4 of the *Arkiv för Botanik* of 1905.

Data on the bud-rot of Cocos are given in vol. 6, no. 3, of the *West Indian Bulletin*.

Vol. 22, part 2 (the second fascicle issued), of the *North American Flora* under the editorship of Professors Underwood and Britton, includes Saxifragaceæ (Small), Hydrangeaceæ (Rydberg), Cunoniaceæ, Iteaceæ, Hamamelidaceæ (Britton), Pterostemonaceæ (Small), Altingiaceæ (Wilson), and Phyllonomaceæ (Rusty). It bears date December 18.

A geographic-systematic account of North American Saxifraginæ is published by Rosendahl as a supplement to vol. 37, part 2, of Engler's *Botanische Jahrbücher*, issued in December.

A new northern Antennaria is described by Greene in *The Ottawa Naturalist* of January.

Habit and bark photographs of *Quercus rubra* are published in *Forest Leaves* for December.

The *Journal of Botany* for January contains a revision of *Ceratostigma* by the new Director of the Kew Gardens, Col. Prain.

The geographic distribution of *Ulmaceæ* is being analyzed by Bernard in current numbers of the *Bulletin de l'Herbier Boissier*.

An analysis of the subgenera of *Ribes*, with a detailed account of the first of these, *Parilla*, is separately issued by Janczewski from the *Bulletin International de l'Académie des Sciences de Cracovie*.

Dahlstedt gives an illustrated account of the Scandinavian forms of *Taraxacum* in *Botaniska Notiser* for 1905.

Floral teratology in two species of *Salix* is discussed by Mott in vol. 2, no. 7, of the *University of California Publications, Botany*.

A monograph of the willows of Ohio, by Griggs, forms vol. 4, part 6, of the *Proceedings of the Ohio State Academy of Science*.

Two new aloes are described and figured by Schönland in the *Gardeners' Chronicle* of December 2.

Kinetostigma is the name proposed by Dammer, in no. 36 of the *Notizblatt des k. botanischen Gartens und Museums zu Berlin*, for a *Chamædorea*-like Guatemalan palm genus.

A. Usteri re-analyzes the morphology of the Coniferous ament in the light of some new *Cunninghamia* material, in the *Revista da Sociedade Scientifica de São Paulo* of September last.

Christensenia is proposed by Maxon, to replace the generic name *Kaulfussia* in *Marattiaceæ*, in the *Proceedings of the Biological Society of Washington* of December 9, in which he also describes a new *Lycopodium* from Guatemala.

The Fern Allies of North America North of Mexico is the title of a new book by Clute recently issued from the Stokes Press of New York. It is illustrated very fully and well.

Setchell gives an account of the parasitic *Florideæ* of California, in *Nuova Notarisia* for April.

A neat little pamphlet on "Lichenology for Beginners" has been separately printed from *The Bryologist* by F. L. Sargent, and is offered by the Harvard Coöperative Society of Cambridge.

The fungi of the Belgian Antarctic Expedition are described by Madame Boinmer and Madame Rousseau in a separate recently issued from the Buschmann Press of Antwerp.

A paper on pathogenic species of *Aspergillus* is published by Constantin and Lucet in series 9, vol. 2, no. 1-3, of the *Annales des Sciences Naturelles, Botanique*.

A paper on the Pyrenomycetæ of Orleans Co., N. Y., by Fairman, constitutes a brochure of vol. 4 of the *Proceedings of the Rochester Academy of Science*, recently issued.

An illustrated paper by House on the fungi and bacteria of plant diseases forms *Circular no. 18* of the Estacion Central Agronomica of Cuba.

An Alternaria rot of apples is described by Longyear in *Bulletin 105* of the Agricultural Experiment Station of Colorado.

A monograph of the apples of New York, by Beach, Booth, and Taylor, constituting part 2 of the *Report of the New York Agricultural Experiment Station for 1903*, recently issued, forms two octavo volumes, illustrated by numerous plain and colored plates.

Alcocer has begun the publication of a paper on the fruits of Mexico in current issues of the *Anales del Museo Nacional de Mexico*.

An illustrated popular account of the tobacco industry of the United States is given by Willey in *The American Inventor* for December.

Montgomery argues, in *The Popular Science Monthly* for January, that *Zea* and *Euchlæna* may have had a common origin, the central spike of a tassel-like structure developing into the ear in the former, and its lateral branches giving rise to the clustered pistillate spikes of teosinte.

Results of corn selection are given by Lyon in *Bulletin no. 91* of the Agricultural Experiment Station of Nebraska.

An account of raffia and its preparation, by Deslandes, has recently appeared from the press of Challamel of Paris.

A lecture on heredity and the origin of species, by MacDougal, is separately distributed from *The Monist* for January.

Notes on the Life History of British Flowering Plants is the title of a volume by Lord Avebury, recently issued from the Macmillan Press.

Harris's conclusions on the influence of Apidæ on the geographical distribution of certain floral types are restated in *The Canadian Entomologist*, October to December.

Foliage phenology in Ceylon is discussed by Wright in vol. 2, part 3, of *Annals of the Royal Botanic Gardens, Peradeniya*.

A portrait of the retiring Director of Kew Gardens, Sir W. T. Thiselton-Dyer, is published in the *Gardeners' Chronicle* of December 9.

A short biographic sketch of Tschirch, with portrait, is published in the *American Journal of Pharmacy* for January.

The October number of the *Nuovo Giornale Botanico Italiano* is dedicated to the memory of Delpino, whose portrait forms its frontispiece.

A catalogue of plants cultivated in the Vilmorin Gardens forms an appendix to the 1904 volume of the *Bulletin de la Société Botanique de France*,—recently issued.

The Journals.—*Botanical Gazette*, December:—Atkinson, "Life History of *Hypocrea alutacea*"; Transeau, "The Bogs and Bog Flora of the Huron River Valley"; Bergen, "Tolerance of Drought by Neapolitan Cliff Flora"; Lyon, "A New Genus of Ophioglossaceæ [*Sceptridium*]."

Botanical Gazette, January:—Chrysler, "The Nodes of Grasses"; Transeau, "The Bogs and Bog Flora of the Huron River Valley"; Merriman, "Nuclear Division in *Zygnema*"; Breazeale, "Effect of Certain Solids upon the Growth of Seedlings in Water Cultures"; Hitchcock, "Notes on North American Grasses—V"; Farmer, "Sporogenesis in *Pallavicinia*"; Moore, "Reply [to the foregoing]."

Bulletin of the Torrey Botanical Club, November:—Howe, "Physiological Studies—II"; Underwood, "The Genus *Alcicornium* of *Gaudichaud*"; Rydberg, "Studies on the Rocky Mountain Flora—XV"; Osterhout, "New Plants from Colorado"; Hastings, "Observations on the Flora of Central Chile."

Bulletin of the Torrey Botanical Club, December:—Murrill, "The Polyporaceæ of North America—XIII"; Rydberg, "*Astragalus* and its Segregates as Represented in Colorado."

Bulletin of the Torrey Botanical Club, January:—Evans, "Hepaticæ of Puerto Rico—VI"; Arthur, "New Species of Uredineæ—IV"; Underwood, "The Genus *Stenochlæna*"; Small, "Studies in North American Polygonaceæ—II."

The Bryologist, January: — Fink, "Edward Tuckerman — A Brief Summary of his Work" (with portrait); Merrill, "Lichen Notes No. 2"; Haynes, "*Cephalozia francisci*."

The Fern Bulletin, October: — Nichols, "*Schizæa pusilla* in Cape Breton"; Woolson, "A Precocious Cystopteris"; Gilbert, "Observations on North American Pteridophytes — II"; Klugh, "*Scolopendrium vulgare* in Ontario"; Davenport, "Reversions and their Fluctuations"; Gilbert, "Mrs. Taylor's Georgia Ferns"; Clute, "A Check List of the North American Fernworts."

The Iowa Naturalist, October: — Cratty, "The Juncaceæ of Iowa"; Fitzpatrick, "The Melanthaceæ of Iowa."

Journal of Mycology, September: — Morgan, "North American Species of *Marasmius*"; Beardslee, "The *Amanitas* of Sweden"; Kellerman, "Index to North American Mycology."

Journal of Mycology, November: — Morgan, "North American Species of *Marasmius*" (*continued*); Atkinson, "The Genera *Balansia* and *Dothichloë* in the United States, with a Consideration of their Economic Importance"; Sumstine, "Another Fly Agaric"; Holway, "Notes on *Uredineæ* — IV"; Sturgis, "Remarkable Occurrence of *Morchella esculenta*"; Kellerman, "Notes from Mycological Literature — XVII."

Journal of the New York Botanical Garden, November: — Nash, "Further Explorations in the Republic of Haiti."

Journal of the New York Botanical Garden, December: — Murrill, "Collecting Fungi in Maine."

Journal of the New York Botanical Garden, January: — Berry, "Fossil Plants along the Chesapeake and Delaware Canal"; Nash, "The *Coco de Mer*, or Double Coconut"; Hollick, "Origin of the Amber found on Staten Island."

The Ohio Naturalist, December: — Gleason, "Notes from the Ohio State Herbarium — V"; Schaffner, J. H., "Key to the Ohio Dogwoods in the Winter Condition"; Schaffner, Mabel, "Free-Floating Plants of Ohio."

The Ohio Naturalist, January: — Tillman, "The Embryo-sac and Embryo of *Cucumis sativus*"; Kellerman, York, and Gleason, "Annual Report on the State Herbarium for the Years 1903, '04 and '05"; Sterki, "Some Notes on *Martynia*"; Hillig, "A New Case of Mutation [*Commelina nudiflora*]"; Schaffner, "Additional Observations on Self-pruning."

The Ottawa Naturalist, December: — Greene, "On so-called *Silene menziesii*"; Fernald, "An Alpine Variety of *Cnicus muticus*"; Fernald, "A New Goldenrod from the Gaspé Peninsula"; Macoun, "Two Rare Fungi [*Cyclomyces greeni* and *Pleurotus subareolatus*]."

The Plant World, October: — Leavitt, "The Defences of the Cockspur Thorn"; Atkinson, "Outlines for the Observation of Some of the More Common Fungi" (*conclusion*); Gray, "Variations in Trillium."

The Plant World, November: — Brackett, "The Mistletoe: Some Recent Observations on its Habit and Structure"; Harshberger, "The Plant Formations of the Catskills"; Bailey, W. W., "How New Plants come in."

The Plant World, December: — Goebel, "Wilhelm Hofmeister" (with portrait); Klugh, "Notes on the Ferns of North-Central Ontario"; Harper, "A Peculiar Hygroscopic Movement in the Capsules of *Kneiffia*"; Clute, "The Defenses of the Cockspur Thorn: Another Interpretation."

Rhodora, November: — Brainerd, "The Use of Accentual Marks in Gray's Manual"; Fernald, "An Alpine *Adiantum*"; Sargent, "Recently Recognized Species of *Crataegus* in Eastern Canada and New England — VI"; Robinson, "A New *Ranunculus* from North-eastern America"; Collins, "Phycological Notes of the late Isaac Holden — II"; Greenman, "*Senecio balsamita* Muhl., var. *firmifolius*"; Fernald, "A Pale Form of *Avena striata*."

Rhodora, December: — Brainerd, "Notes on New England Violets — III"; Fernald, "A Northern *Cynoglossum*"; Cushman, "A Contribution to the Desmid Flora of New Hampshire" (*continued*).

Rhodora, January: — Ames, "*Habenaria orbiculata* and *H. macrophylla*"; Brainerd, "Hybridism in the Genus *Viola* — II"; Fernald, "A New Geum from Vermont and Quebec"; Davenport, "A Hybrid *Asplenium* New to the Flora of Vermont"; Ames, "*Spiranthes ovalis*"; Blanchard, "A New *Rubus* from Connecticut"; House, "Observations upon *Pogonia (Isotria) verticillata*"; Fernald, "A Handsome Willow of the Penobscot Valley"; Brainerd, "*Nephrodium filix-mas* in Vt."; Woodward, "Notes on Two Species of *Sporobolus*."

Torrey, November: — Harshberger, "The Plant Formations of the Adirondack Mountains"; Murrill, "A Key to the Brown Sessile

Polyporeæ of Temperate North America"; Taylor, "On the Occurrence of *Daucus carota* in Taiti"; Murrill, "Tomophagus for Den-drophagus"; Kellerman, "The Gray Polypody in Ohio"; Cockerell, "A Laciniate Rubus"; Macloskie, "Duplex Names."

Torrey, December:—Harper, "A Statistical Method for Comparing the Age of Different Floras"; Kraemer, "Artificial Coloring of Flowers"; Murrill, "A Key to the Agaricæ of Temperate North America"; Britton, "The Cuban Columnæas"; Bates, "*Astragalus lotiflorus nebraskensis*"; Cannon, "A Curious Cactus Fruit."

Torrey, January:—Andrews, "Polarity in the Weeping Willow"; Gleason, "Notes on some Southern Illinois Plants — III"; Rydberg, "Grayia or Eremosonium"; Cockerell, "Rhus and its Allies."

The fourth *Year Book* of the Carnegie Institution of Washington, recently issued, contains abstracts of the reports of investigators to whom grants have been made for botanical research.

The following botanical papers, or abstracts of them, are contained in the *Report of the Eighth Geographic Congress* (Washington, Govt. Printing Office, 1905):—Cowles, "A Remarkable Colony of Northern Plants along the Apalachicola River, Florida, and its Significance"; Cowles, "The Importance of the Physiographic Standpoint in Plant Geography"; Harshberger, "Methods of determining the Age of the Different Floristic Elements of Eastern North America"; Drude, "Die Methode der pflanzen-geographischen Kartographie, erläutert an der Flora von Sachsen"; Anderson, "The Flora of Connaught as Evidence of the Former Connection with an Atlantic Continent"; White, "The American Range of the Cycadofilices."

PUBLICATIONS RECEIVED

(Regular exchanges not included)

- ANDREWS, M. R. S. *Bob and the Guides*. New York, Charles Scribner's Sons, 1906. 8vo, 351 pp., illus. \$1.50.—FREEMAN, E. M. *Minnesota Plant Diseases*. St. Paul, Minn. xxiii + 432 pp., illus.—HEMENWAY, H. D. *Hints and Helps for Young Gardeners*. Hartford, Conn., Published by the Author, 1906. 8vo, 59 pp., illus. \$.35.—HOWE, R. H., JR., AND M. A. *Common and Conspicuous Lichens of New England*. Part I. Boston, W. B. Clarke and Co., 1906. 12mo, pp. 1-22, illus. \$.50.—HOWE, R. H., JR., AND M. A. *Common and Conspicuous Lichens of New England*. Part 2. Boston, W. B. Clarke and Co., 1906. 16mo, pp. 23-39, illus. \$.50.—LACOUTURE, C. *Hépatiques de la France. Tableaux synoptiques des caractères saillants des tribus, des genres et des espèces*. Paris, Paul Klincksieck, 1905. 4to, 78 pp., illus.—LOTSY, J. P. *Vorlesungen über Deszendenztheorien mit besonderer Berücksichtigung der botanischen Seite der Frage*. Erster Teil. Jena, G. Fischer, 1906 [1905]. 8vo, xii + 384 pp., 2 pls., 124 figs. 8 Mk.—MCMURRAY, C. A. *Special Method in Elementary Science for the Common School*. New York, The Macmillan Co., 1905. 12mo, ix + 275 pp.—MOORE, J. H. *The Universal Kinship*. Chicago, Chas. H. Kerr and Co., 1906. 12mo, x + 329 pp. \$1.00.—PRATT, H. S. *A Course in Vertebrate Zoölogy. A Guide to the Dissection and Comparative Study of Vertebrate Animals*. Boston, Ginn and Co., 1905. 8vo, x + 299 pp.—SABINE, W. C. *A Student's Manual of a Laboratory Course in Physical Measurements*. Revised Edition. Boston, Ginn and Co., 1906. 8vo, vi + 97 pp. \$1.25.—SCHILLINGS, C. G. *With Flash-light and Rifle. Photographing by Flash-light at Night the Wild Animal World of Equatorial Africa*. Translated and abridged by Henry Zick, Ph. D. New York, Harper and Brothers, 1905. 8vo, xiii + 421 pp., illus.—WILLSON, R. W. *Laboratory Astronomy*. Boston, Ginn and Co., 1905. ix + 175 pp., figs. \$1.25.—ZSCHIMMER, E. *Eine Untersuchung über Raum, Zeit und Begriffe vom Standpunkte des Positivismus*. Leipzig, W. Engelmann, 1906. 8vo, 54 pp. Mk. 1.20.
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